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H. W. PARKHURST

President, Western Society of Engineers

1904

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VOL. IX. FEBRUARY, 1904. NO. 1.

HEATING FROM A CENTRAL STATION.

W. H. Pearce, M. W. S. E.

Read December 18th, 1903.

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pounds; the exhaust at a pressure of 40 pounds was to return to another pipe in the street, from which buildings were to be heated and the condensation passed to the sewer. This scheme was a failure. It reflected credit however, on the inventor and (like other failures) suggested to the intelligence of others, possibilities in the same general direction, which have been seized from time to time. The writer hopes to show in this paper that today with proper appliances and experience, heating from a central station is a success.

It is quite generally assumed to be a matter of common knowledge "how to construct a heating plant." In fact, some engineers, while giving their clients the best advice as to the selection of an engine or boiler for the purpose required, put in extra time trying

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ERRATA.

Journal, Vol. IX., No. 1.

Page 57.—Beginning of 26th line should read, "at the back of the grate."

Page 77.—End of 14th line, $\frac{1}{25}$-inch should read "1.25 inch."

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HEATING FROM A CENTRAL STATION.

W. H. Pearce, M. W. S. E.

Read December 18th, 1903.

In calling attention to the subject of heating from a central station, this paper refers particularly to that class of station where coal is used as raw material, to be manufactured into heat which is distributed through the streets and alleys of a city or town by means of suitable conduits, and sold to consumers. It does not refer to that class of central stations operated in connection with buildings, colleges, asylums, and similar institutions. This is not because the construction of the latter class is unimportant, but because the difficulties attending the construction of the former, such as the interference with sewers, gas mains and water pipes, the length of mains, convenience, adaptation and (of most importance) mechanical and commercial success, necessitate its consideration as a subject apart from other branches of the heating business. The subject has received comparatively little attention until lately. Heating, however, has been done in this manner ever since steam came into prominent use. In this country Mr. Birdsell Holly was one of the pioneers. Thirty years ago he applied for a patent on a system of pipes whereby steam coming from a central station was to supply power for operating engines at a pressure of about 80 pounds; the exhaust at a pressure of 40 pounds was to return to another pipe in the street, from which buildings were to be heated and the condensation passed to the sewer. This scheme was a failure. It reflected credit however, on the inventor and (like other failures) suggested to the intelligence of others, possibilities in the same general direction, which have been seized from time to time. The writer hopes to show in this paper that today with proper appliances and experience, heating from a central station is a success.

It is quite generally assumed to be a matter of common knowledge "how to construct a heating plant." In fact, some engineers, while giving their clients the best advice as to the selection of an engine or boiler for the purpose required, put in extra time trying to avoid the use of devices now being manufactured especially for this purpose and devise something themselves. Sometimes a snag is encountered, but as it is underground it is not considered material to the success of the general plant. Some time ago a gentleman, explained how easy it would be for him to put a pipe in a sawdust box and use exhaust from an engine to heat several blocks of buildings. He received the same advice that "Punch" gave to those about to get married, viz.: "Don't."

Writers on the general subject of heating, who have covered hundreds of pages in exhaustive explantion of tests of things that are common, and which everyone has accepted long ago as a practically perfected product, pass this branch of the subject lightly, with just sufficient said to assure the reader of the fact that such plants are failures. Some organizations have appointed committees to investigate this subject, and the writer is credibly informed by a member of such a committee that they have been working on the matter for a year, and have asked for further time in which to make a better report. This suggests that there may be more in the subject than appears on the surface.

For the purpose of this paper, the writer has made inquiry for some tests, or clearly defined methods that may be accepted as a true gauge whereby the relative efficiency and merit of devices and methods may be established, but so far he has not been successful. That there may be something of this kind, he cannot doubt.

It is not the purpose to give any minute details of the operation that such tests might disclose. The time may come soon however, when this Society will be as agreeably entertained in a comparison of tests of insulating or heat retaining substances and construction for this purpose, as it has been in the past with tests of heat producing substances and apparatus. Certainly one is as important as the other when we consider the wasteful loss of heat energy that is now going on in various lines of practice. The present effort may offer a substantial suggestion as to one of the means whereby we may profitably utilize such coals of our State for domestic heating purposes, which may be purchased in car lots at the rate of 1,200,000 heat units for 10 cents. For a like amount of money you are now getting, in the form of anthracite coal, only 378,370 heat units, or approximately 32 per cent of equivalent heat value. Certainly the subject is alluring from the promoter's standpoint, and should be interesting to the engineer.

A rough estimate of the number of stations constructed within the last thirty years in this country may be 300, one quarter of which has been put in operation within the last few years. It is fair to say that but a small proportion of those built have been, or are likely to be, successful. Such cities as Detroit, Milwaukee, Burlington and others, have abandoned pipes in their streets.

Central station heating plants usually have the general public as investors; you are not dealing with a railway man, who knows the locomotive you are offering him as well as you know it yourself. You are dealing with those who know nothing of the subject from an engineer's standpoint; in fact, an expert opinion would hurt the case, especially if the proposed construction be poor. The shrewd and prominent citizen however, can properly be induced to give the thing a boom. The fact that he has something in it, rather than its own merit (if it has any), induces others to make investments. The shrewd promoter shows how electric light costs nothing when made in connection with a heating plant. The shrewd and prominent citizen gets up a meeting, a committee is appointed to investigate; they are taken to a plant put in operation under the proposed conditions; the *streets are shown*, under which the pipes are laid; the boiler is pronounced a marvel; the top of the smokestack is found to exist without smoking; everyone praises the accomplishments of the inventor; stocks are selling high; it is shown that by this invention the heat passes out and returns again with only 20 degrees of loss. Nothing is said however, of the fact, that the 20 degrees probably represented the pumping of 3,500,000 gallons of water per day, against 60 pounds pressure and at the cost of 40 tons of coal. On the return, a mass meeting is arranged, glowing speeches are made, the company is formed, and in goes the plant. When it develops that some do not get heat, the steam fitter is said to be at fault, not the station or its apparatus; the company kindly furnishes (free of charge,) the services of an expert, who generally advises an increase of radiation, averaging say 25 per cent. When this is nicely installed, it is found the company is not making money; therefore, it repudiates its ingenious scheme of charging a price for heat by measurement of the outside of the building, and charges by the square foot of radiation, which is now excessive, owing to the low temperature of the heat furnished. The customer cannot very well make objection at this stage. His house cost him say $400 to fit up with steam heat, and his furnace has been sold for junk; hence, it is cheaper to continue at the advance than take the entire thing out and buy a new furnace. He is further convinced of its cheapness, by the fact that all companies that have gone through this process have had to raise rates. The schedules are shown; he finds there are those who are paying 30 cents per foot of radiation, while he is asked only 20 cents. The explanation, of course, is withheld, that the 30 cent rate is for heat requiring only half the amount of radiation.

Another plan is the one of the man who carries in his pocket some small device, probably costing 50 cents, which he declares is competent to make the investors rich, as on it hangs all the laws of heating and the profits in the enterprise. He proposes its use; illustrates buildings and gives references to show how extensively the device (which he calls his system), is used; his patents on it are many; he calls in the local man (who incidentally is to receive 10 per cent), and all his assertions are confirmed. If his plan is adopted, he assumes no responsibility for the laying out of the mains; any one may do that, he tells you, or he may recommend a man. He guarantees nothing but what known laws guarantee him. He furnishes his devices, collects his royalty, pays his assistants, asks and usually gets a good recommendation to go elsewhere.

These things are not engineering matters, but as the subject is broad, the writer feels that he would not be doing it justice without giving a correct view from all standpoints. Furthermore, it is proper as an illustration of one of the reasons of failure. You may think it is an overdrawn picture but it is based on knowledge of facts which cannot be successfully refuted, and moreover such cases as are cited, and many others, will be found common if investigated.

There are other reasons why heating from a central station is not always a success. One is injudicious location. If a proposed station be in a small town where coal is sold by the bushel direct from the mines, and the inhabitants are of the class which use stoves, the chance for success would in any event be an uphill proposition. If, on the contrary, a rather wealthy town be selected (as for instance, a small city near Chicago), success would be reasonably assured. Locate the station on a railway track, and if possible in the middle of the district to be heated; four mains running in four directions from the station is a more efficient plan than one long main carrying heat from the station to a central distributing point. Having selected the location, waste no time in presuming you can do as well as another by copying his ideas. Local conditions must govern in each case; such for instance as the number of days in the heating season; price of coal and its heat value; average outside temperature; character of service; distance; losses, etc. It is therefore proper that procedure be based upon business methods, which in this case is chiefly good engineering.

For the proper presentation of this feature you will pardon reference to some first principles, as it is desired to keep before you the cost and efficiency of heat as manufactured in the ordinary manner by the customer; the conditions, efficiency, and cost of manufacture at the station; and the conditions and efficiency in methods of transmission. With these understood you will formulate in your own minds an answer to the question: "Does it pay, and how?"

Imagine a simple box, inside of which the temperature is 70 de-

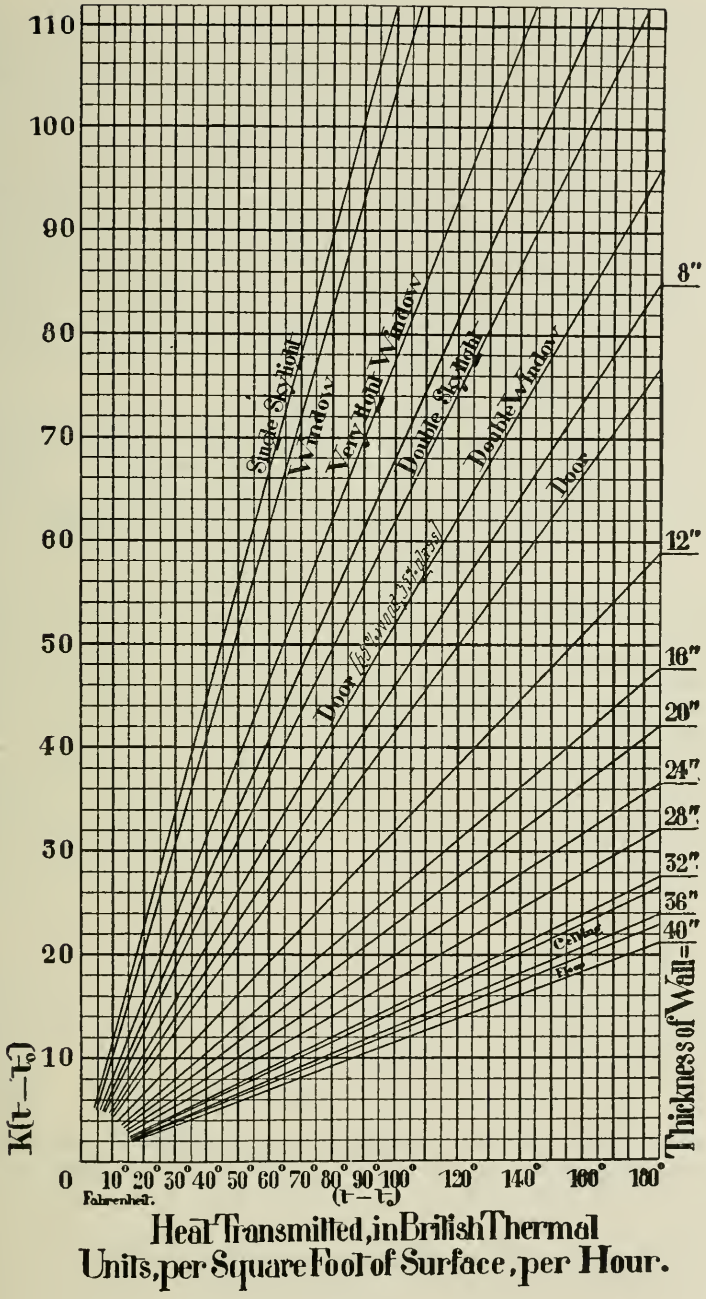

110
100
90
80
70
60
50
40
30
20
10
0
$K(t - t_0)$
Single Skylight
Window
Very Tight Window
Double Skylight
Double Window
Door
Door (65% wood 35% glass)
Ceiling
Floor
8"
12"
16"
20"
24"
28"
32"
36"
40"
Thickness of Wall =
10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 120° 140° 160° 180°
Fahrenheit.
$(t - t_0)$
Heat Transmitted, in British Thermal Units, per Square Foot of Surface, per Hour.

Fig. 1.

grees, while the outside temperature is zero. It is manifest that the temperature will be retained indefinitely if it were not for the law which tends to equalize the difference of temperatures, this law operating in a ratio dependent upon the transmitting power of the material, of which the walls of the box are constructed.

Fig. 1 is a diagram prepared by Mr. A. R. Wolff, which the writer accepts as a standard method of determining the loss due to the tendency to equalize. Another thing to have in mind, that is usually lost sight of, is that if an apparatus or device that generates the heat be placed within the box, there can be no loss of heat to the box, because that which may leak or be lost from the apparatus is lost or leaked into the box. If however, the heat be generated outside of the box and transmitted to it, any leakage is a loss to the box to be heated.

Substitute a house for the box and proceed to find out the cost of heat as manufactured by the customer. The efficiency of the apparatus to the occupant is the cost of production of that heat which heats his living rooms; not that which heats the cellar or is in ashes nor diffused in an unused portion of the building. The former may be called the efficient heat, which from some experiments made by the writer and deductions from the experience of others, may be generally taken as 75 per cent of the heat value of the coal. Assume this to be correct, and a simple problem of arithmetic gives the cost of heating an average building per year; also the cost per million heat units as 45 cents. If you take into consideration the damage to draperies, the dirt in the house and

COST OF HEATING A TYPICAL BUILDING.

Cost of coal per ton,	$7.50
Average days in the season,	200
Coal used in tons	10.8
Heat value per pound B. T. U.	14,000
Efficiency	75%
Average outside temperature,	35°
Average pounds per day,	108
Average pounds per hour,	4.5
Heat units value,	47,250
Average heat used per minute,	787.5
Cost of coal per season,	$81.00
Handling at 10%,	08.1
Repairs on apparatus at 10%,	08.1
Kindling, matches, etc. at 5%	4.00
Cost per season,	$101.20
Cost of coal per pound,	$ .00375
Cost of coal per million B. T. U.,	0.358
Handling. at 10%,	0.0358
Repairs at 10%,	0.0358
Kindling, etc. at 5%,	0.0179
Cost per million B. T. U.,	$0.4475

the inconvenience of getting up on a cold morning to renew fires, you might place it higher. In fact 50 cents is not too high if all the items be considered. These figures are not intended to suggest that heat should be sold at a price less than the cost of coal. Many mistakes have been made in accepting the customer's coal bill as a basis. Heat from a central station should be sold at a price that is fair, in consideration of its cost of production and transmission, the investment, and the character of the service rendered.

Having selected the location of the station and found for what amount the proposed customer can manufacture heat, let us see at what price heat can be manufactured at a central station. To do this, assume, for convenience, a direct steam-heating station which consists in its chief elements of boilers and a pipe to conduct the steam to the street mains. The efficiency of this form of apparatus needs no description. For this purpose however, we desire to know at what price per million heat units it can be supplied to the pipes, taking into consideration the operation of the station 24 hours per day. We must also consider the increase and decrease of load, due to the temperature of the outside atmosphere; the fact that the water pumped into the boiler has no means of being heated except by the exhaust from the feed pump, the cost of coal and its heat value, labor of handling the different kinds, all at this station.

If you buy coal for $2.00 per ton, having say 12,000 heat units value, and the efficiency of your plant is, say 60 per cent; the cost for producing one million heat units would be $0.137; adding 12 per cent for handling and 5 per cent for depreciation you have in round fiigures, 16 cents as the cost of one million heat units. There is but one way of manufacturing this heat; viz., the boiler process. In a direct steam heating station a battery of boilers and a steam pipe entering the ground are its chief elements. In a live and exhaust steam station the exhaust pipe from the engine also furnishes heat after it has passed from the engine. If induced circulation is used, then a return pipe enters the building and a vacuum pump becomes an additional element. If hot water is the medium, circulating pumps installed to circulate the water and heaters to transfer the heat of the exhaust steam to the water are used instead of the vacuum pump.

COST OF MANUFACTURING 1,000,000 HEAT UNITS AT STATIONS.

Price of coal per ton, in car lots,	$2.00
Heat units per pound,	12,000
Efficiency of Boiler Plant,	60%
Cost of coal per million heat units,	$0.137
Cost for handling, at 12%	.016
Cost for depreciation, at 5%	0.007
Total,	$0.160

Having arrived at the cost of heat manufactured at the station and the cost at which the customer can manufacture it, note that whatever gain or loss there may be in any method is undoubtedly in the transmitting apparatus or process between the station and the customer, as the amount to be furnished and the cost of manufacture is identical by any method.

Probably the *most* mistakes in this class of work have arisen from an improper consideration of the question of transmission. A good thing in heating is like other good things, it costs money. Still strange as it may seem, quite a large majority of investors ignore the fact that the entire aim of engineering practice is to produce that which is competent to do the work and pay the best dividend, not merely to show how cheaply pipe and other materials may be buried underground.

Imagine an engineer examining a central station and finding a heater of 600 square feet of surface, rightly calculated to transmit heat at 800 heat units per square foot per hour, for each degree of difference in temperature. If he walks outside and finds four miles of pipe underground, averaging 1 foot of surface to each lineal foot, he calculates about 21,000 square feet of surface to transmit or lose heat. If he finds the snow melted on top of the ground, the said pipe being three feet below the surface, he calculates the loss. He might also learn that some customers do not get enough heat, while some get too much, and would reason that the flow was not equalized. He sees men digging in mud, to repair a gasket blown out on account of buckling or the strain on the main. He looks for means for taking care of expansion and finds a common slip joint, as good as new and 600 feet away; in fact it has never moved since it was put in. As to the flooding of the main, and the presence of surface water, he reasons that *such* heating mains are excellent condensers. He may find leakage caused by too many flimsy joints, taps or connections. His calculations might show a loss of $6,000 worth of coal a year.

Attention is called to these things, not for the purpose of fault-finding, but simply as an illustration of some of the difficulties that have to be met and overcome. It is no wonder that mistakes have been made, but if we persist we deserve censure. Bear in mind that you are liable to have eight customers to every hundred feet in the business districts. You cannot always turn your pipe at right angles to take up expansion; neither have you a convenient iron post to anchor the pipe to, or a building that insures drainage. Your pipe must run up and down grade and be properly drained in either case. You are confined to a height of, say, three feet and a width of, say, three feet to get in all that is necessary for proper operation.

Fig. 2 illustrates a typical street and some cross-streets, showing a line of mains and connections to various stores, brick residences and frame residences; the stores are calculated at 25 feet apart. Bear in mind that the mains must avoid other pipes; in case a 36-inch water main obstructs the path, the heating main must either go over or under; all connections to buildings running at right angles to the mains must avoid other pipes in the streets running parallel to the mains. The illustration indicates one of the methods, in which case the connections are tapped into the mains with about a 1-inch water cock. In expanding, say, 6 inches the main carries everything with it. If the owner of the plant had 400 customers,

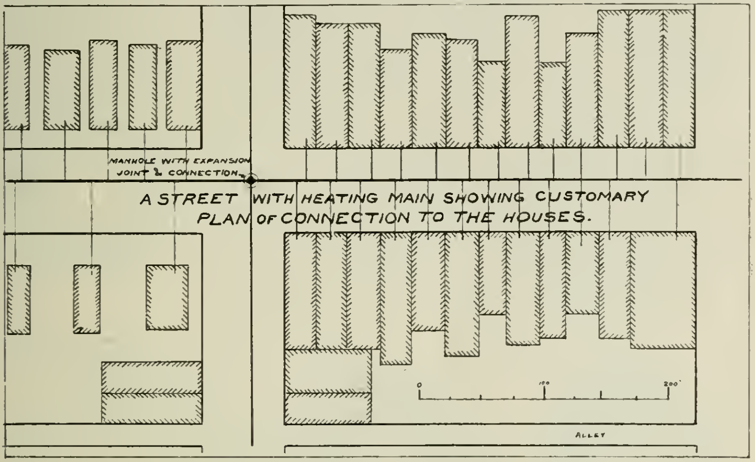

MANHOLE WITH EXPANSION JOINT & CONNECTION.
A STREET WITH HEATING MAIN SHOWING CUSTOMARY PLAN OF CONNECTION TO THE HOUSES.
0
100
200'
ALLEY

Fig. 2.

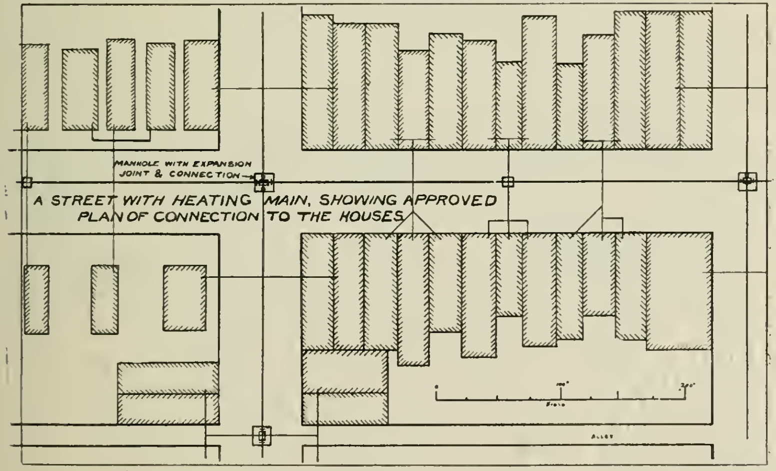

MANHOLE WITH EXPANSION JOINT & CONNECTION
A STREET WITH HEATING MAIN, SHOWING APPROVED PLAN OF CONNECTION TO THE HOUSES
ALLEY

Fig. 3.

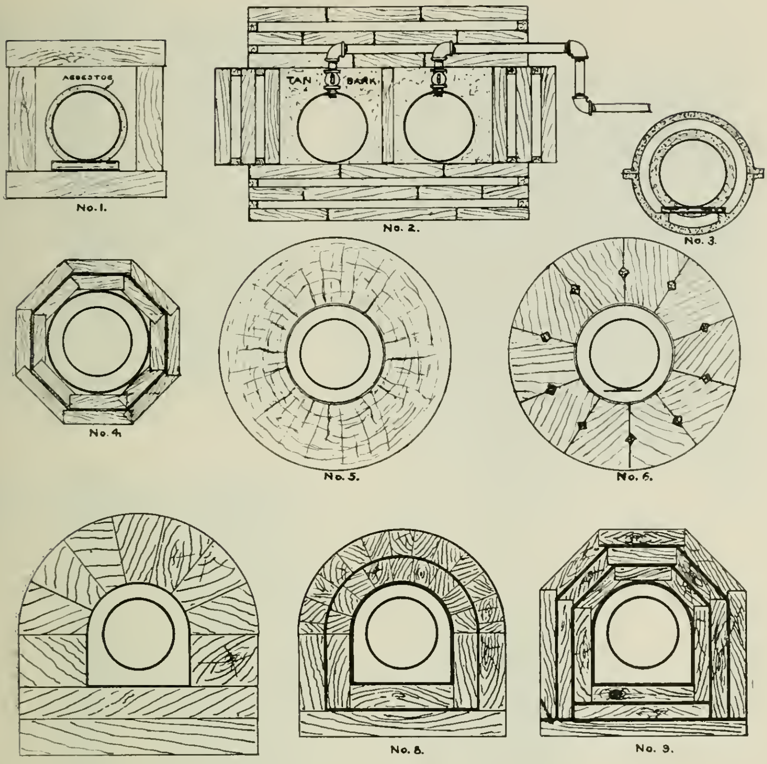
he would have 400 cuttings in his insulation to lose heat, 400 small connections, 400 chances for leakage, 400 chances to one that a big job of repairs would be necessary on account of improper provision for expansion, and 400 chances to one that with a poor insulation, large mains and low temperature, he would be losing money.

Contrast this with Fig. 3 and see the simpler method, one substantial connection serving at least six customers (three one side of the street and three on the other), or three connections to the block. Notice that the stores at the end of the block connect to the mains on the side streets. This view also illustrates different methods of getting to buildings.

In the system of mains there should be provided the following:

1. Substantial anchorage.
2. Some mechanically correct device for taking care of expansion adapted to this class of work.
3. Equalization of strain due to expansion.
4. Freedom to expand.
5. Flexibility, so that a connection of any reasonable size may be readily made to a substantial fitting.
6. Tight joints.
7. Facilities for the interchange of fittings.
8. Provision for outlets from substantially fixed points.
9. Accessibility of working parts—joints, valves, etc.
10. Provision for the maintenance of the highest temperature and velocity.
11. Proper equalization and distribution of heat.
12. Minimum expense in making connections to buildings by having the least possible number of connections to the mains.
13. Thorough drainage of all surface water to protect insulation and prevent flooding.
14. A form of insulation or casing which offers freedom of movement to the pipe, is waterproof, protected from decay, has the least tendency to open at the joints (either from weight upon it or the changes of temperature), and that offers the highest resistance to the escape of heat.

Fig. 4 shows forms of cases that are usually considered. The views are from sketches, using the same sized pipe to show the relative thickness. No. 1 is the common box which may be successful on short runs, but under the general conditions referred to it would be entirely inadequate. No. 2 is a common form used in hot water plants; rough 1-inch boards, after being dipped in oil, are nailed to ½-inch strips placed at right angles. In some cases a layer of paper is put between the boards, the claim is that the strips form dead air spaces and give good results as insulators. There are two pipes in the same box, the outgoing and the returning, with a board partition between. These mains carry varying



PIPE CASINGS

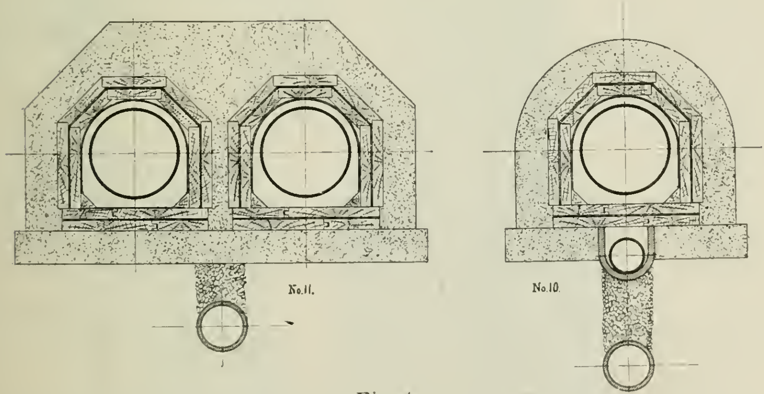


Fig. 4.

temperatures, depending upon the outside temperature of the atmosphere; ordinarily the outgoing might be 180 degrees, and the return 160 degrees. The mains are placed on the floor of the box and sometimes sawdust, mineral wool or tan bark is put inside the box with the pipe. No. 3 shows a construction with tile having a shelf for a roller to support the pipe, the tile being covered with some form of pipe covering.

No. 4 is a planked construction, machined and fitted in the manner shown, the inside lined with tin, then $\frac{1}{16}$-inch asbestos, wood, corrugated paper, wood and asphaltum pitch on the outside, all in the order named; it is bound with wire to keep the joints from opening because of the weight of earth on top or changes of temperature, which is from 60 to 230 degrees. The length of each section is 8 feet and the ends have mortise and tenon joints. No. 5 is known as the solid log casing, in 8-foot lengths, with mortise and tenon joints, is tin-lined with asphalt pitch outside. No. 6 is similar to No. 5, except being made in sections to prevent checking. It is bound with wire to prevent opening of joints due to weight of earth and changes of temperature; it has asbestos lining and asphalt pitch covering.

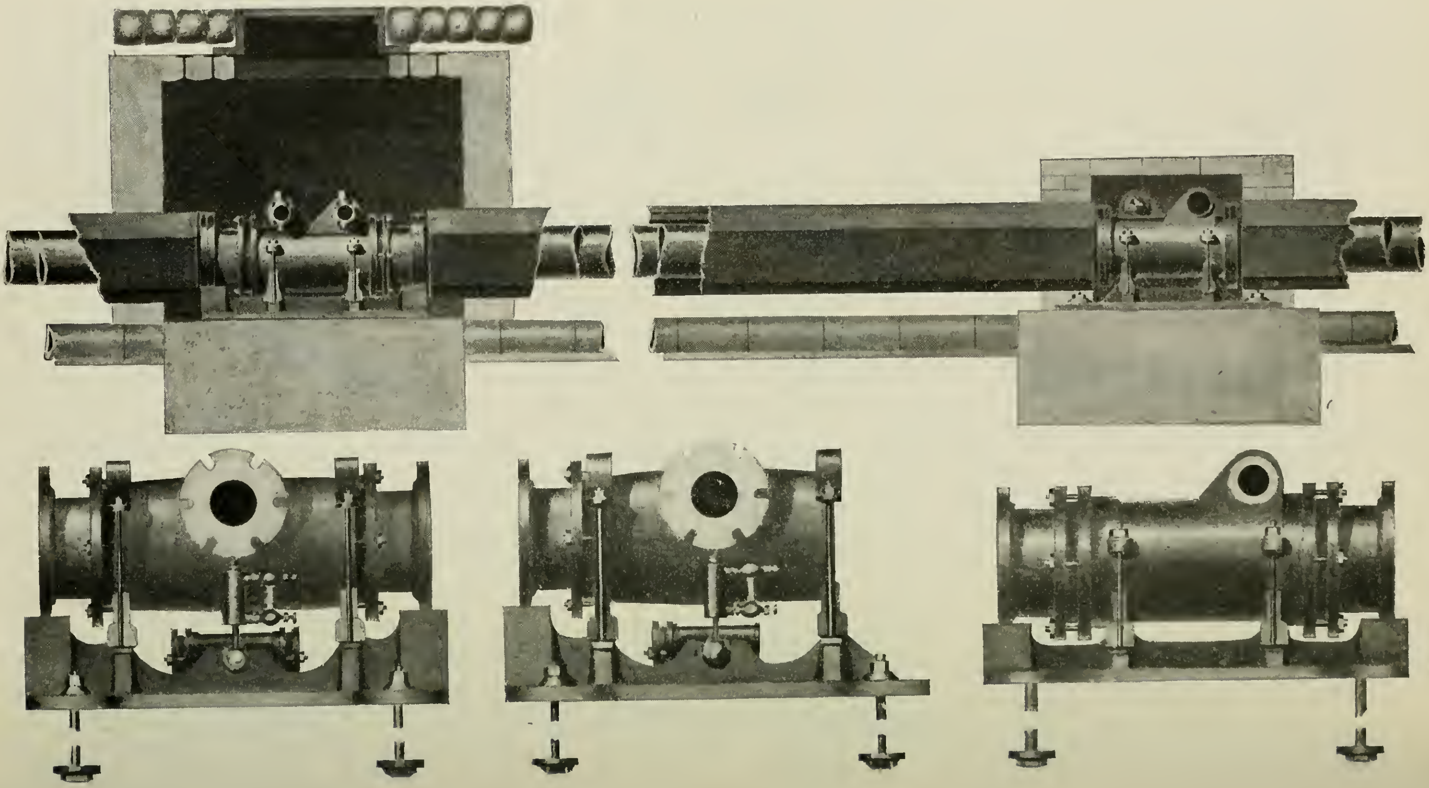
No. 7 is made in 8-foot sections with flat base, has vertical sides to prevent opening of the joints due to weight of earth, tin and asbestos lining, mortise and tenon joints at ends and asphalt pitch covering.

No. 8 is the same as No. 7, but made of two layers with wool felt between the layers, to further prevent transmission of heat.

No. 9 is of plank construction, lined with tin and $\frac{1}{16}$-inch asbestos, machined and fitted woodwork; wool felt is between the woodwork which is coated with asphalt pitch on the outside.

No. 10 is a similar construction with concrete on the outside. This is adapted to streets with heavy traffic; it also shows a return pipe and drain tile. No. 11 is a similar construction and having two pipes for hot water. With the cheaper forms of construction, as with No. 2, a common practice in making connections to the mains for a customer's supply is to cut into the insulation, drill and tap into the main pipe, and screw in a one inch water cock. The pipe is led off about at right angles with the main, and is supposed to take care of the expansion movement. For laterals at cross streets use is made of crosses or ties, which are also used as anchors for the main pipe. Common slip joints are placed about 600 feet apart. With this construction sub-drainage is geneally omitted. A single pipe construction, for hot water, has been used, where Y outlets are used with a 2-inch supply and return to the same main. To force circulation, a valve, or stopper is also used in the Y fittings. The insulation of this work is generally of the cheaper plank construction.

An illustration of a form of two-pipe construction for hot water is shown. The pipes are put in separate casings, the object being to prevent any tendency to equalize. The anchorage is a concrete foundation, the anchor special being mounted on and bolted to a



sole plate, supported by the concrete foundation. Stationary, double ended, expansion joints are used instead of movable ones to equalize the end thrust and they are usually placed about 300 feet apart; being stationary they, like the anchor special, form excellent outlets. The idea here is to use as few outlets as possible, and still care for all customers in the manner previously shown. The outlets may be used either for connections to customers or for a lateral or branch main. Being interchangeable it is an easy matter to take out an entire fitting and put in one with larger openings, if it were advisable to run a lateral on some street, or if a customer required a larger supply pipe. In this construction the casing is left intact, connection being only from the fittings which are accessible in manholes as shown. The fittings have offset outlets, so that the going and returning connection pipes do not interfere, and outlets are on both sides, as customers are on both sides of the streets. In this construction, economy of space in height is a feature, together with a construction designed to carry any temperature that may be put upon it. With this construction is provided a tile drainage for surface water, connected at intervals with the city sewers.

Modifications of the construction shown suggest themselves whether for a one-pipe direct steam system, or for a return steam and induced circulation plan. Various forms of expansion joints—either sliding sleeves or copper diaphragms may be used. These expansion joints are combined as previously stated with the outlets, and on substantial concrete anchor bases. Valves can also be provided in the construction of these special fittings to regulate the supply to the laterals. As indicated, these special fittings are set in manholes, to be readily accessible. With this arrangement the casings are not disturbed or cut into, all connections being made at the special fittings—in the manholes—which are also anchorages. Proper under drainage connected to the sewer system is very desirable and generally installed—for if the heating mains become flooded with ground water there is much less of heat.

Condensation is drained from the mains by means of a very simple device. The joints acting as water separators, condensation from the lowest part passes to a receiver, where, with the valve closed, the rate may be gauged by the water glass; then the valve may be opened just sufficient to let it escape. A thermometer is provided so that the discharge may also be regulated according to the temperature. Also one of the many forms of thermostatic traps for the same purpose, when applied in buildings, the thermostat, which is a hard rubber composition, is set to open when the temperature is, say, at 212 degrees; also a float trap, consisting of a copper float, which rises as the condensation accumulates, and allows its passage to the return pipes. The last two are used in buildings or possibly in other methods of construction for the street mains.

A hot water system in which the pipes enter the building, passing through a controlling valve, then to the radiators and return to the main in the streets, the flow being regulated on the return as temperature demands. Fig. 5.

Next, a return steam or induced circulation system, in which, after the pipes enter the buildings, the condensation is trapped and returned through a thermostatic trap, the dry steam passing to the radiators, on the return side of which is placed a trap to prevent the vacuum from causing the flow to short circuit, by closing the return as soon as the temperature required has been attained in the radiator. Condensation after being metered, passes to the return pipe and to the station.

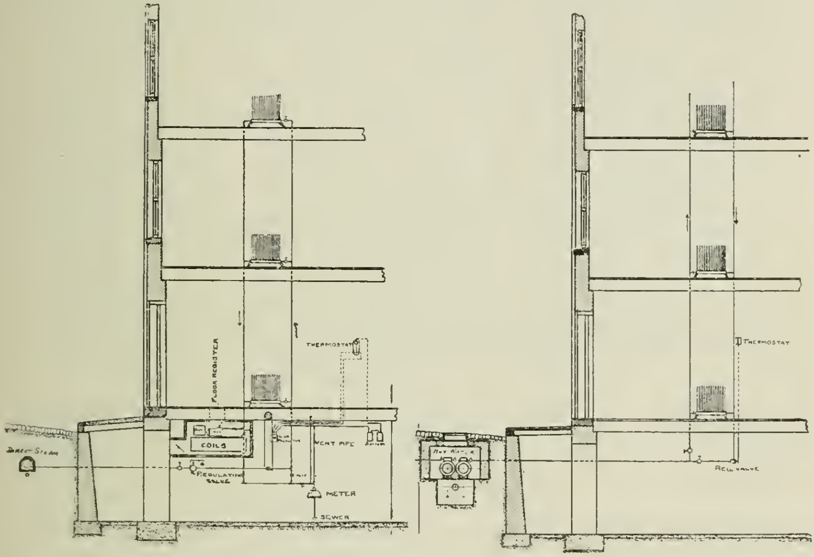


Fig. 5.

There is also a direct steam heating connection in which the steam enters the building, passes the controlling and pressure reducing valves to the radiators. The condensation is trapped into a cooling coil or indirect radiator; air for ventilation is admitted through a tin lined box, passes over the coil and provides ventilation. The condensation gives up its heat, to the extent of reducing the temperature to about 125 degrees, then passes through a meter which measures the amount of steam condensed, and from which the condensation flows to the sewer. Fig. 5.

Special fittings are designed for underground mains, which are similar to those used in general, and include 90 degree angle joints used for turning angles; ball joints used for the purpose of bringing flanges parallel to each other when necessary, or if the mains assume a slight angle, etc.

The varying rates charged for services are a source of material error. In hot water plants it may be 1 cent per season for each three cubic feet of space in any and all kinds of buildings; another charges 12½ cents per square foot of radiation; while another asks one-fifth the price of the coal per ton in cents per foot of radiation which, at $2.00 for coal, would be 40 cents per square foot of radiation. For a steam system the charge varies from $2.50 to $4.00 per thousand cubic feet of space heated, (inside measurement) to a price of $8.00 per thousand feet for any and all buildings, or it may be 18 cents to 45 cents per square foot of radiation. Another method coming into use is meter measurement, from 30 to 65 cents per thousand pounds of condensation. This, of course, is not applicable in a hot water system.

Rates seem to have been applied indiscriminately, without regard to cost or the heat units furnished. The latter is undoubtedly the correct principle. A rate per cubic foot is open to the objection that consideration is not given to the fact that one building, owing to its construction, requires less heat than another. A charge per square foot of radition is open to the objection that a square foot of radiation used in a hallway, a post-office or a butcher's shop, is usually called upon to do twice the work it might if located in a parlor. Again, a rate of 30 cents per square foot of radiation for heat at a temperature of 140 degrees inside the radiator, requiring 715 square feet of radiation in the building, is not an equivalent of the same rate for an inside temperature of 220 degrees, requiring 333 square feet of radiation.

The meter method has some advantages, among which is the fact that the customer may shut off the heat from any part of the building not in use. It is a point of economy for the station, as the customer will be more liable to shut off the heat than to open a window, which he might do if the heat be furnished by contract. Meter measurement has the disadvantage of not taking into consideration the value of the service, which should be done in cases such as the heating of an office room, where if it were not for the heating plant the occupant would have to put up a stove. The writer's suggestion is that the meter charge per thousand pounds, to those using small quantities, be increased; for instance, assuming the base rate to be 50 cents, charge to those averaging 20,000 pounds condensation per month, 55 cents; for 15,000 pounds, 60 cents; for 10,000 pounds, 65 cents; and for 5,000 pounds, 70 cents per thousand pounds of condensation. This should be satisfactory to the customer in the case mentioned, add materially to the revenue of the plant, and correct an error. This base rate men tioned should be determined for each locality, and should depend on the cost of the coal, average outside temperature, number of days of service, cost of plant, heat value of the coal used and cost of labor to handle the various properties.

A table has been prepared for this paper to show the variation, in which all the items are considered, with the same margin of profit added. It assumes 35 degrees as the average temperature; $2.00 per day for labor; feed water at 180 degrees; drip to sewer, 180 degrees; then bases the rate on the heat value of the coal and its price per ton, For coal at $2.00 per ton and with 11,250 B. T. U., the rate is 50 cents, while for coal at $4.00 per ton, and 14,000 B. T. U. the rate is 70½ cents.

DATA:—
LABOR $2.00 FEED WATER 180°
SEASON. 200 DAYS. DRIP 180°
MEAN TEMPERATURE 35° (OUTSIDE).

HEATING RATES FOR 1000 LBS. WATER.
IN CENTS.

TO FIND RATE PER SQUARE FOOT FOR HEAT DELIVERED IN BUILDING AT 220° MULTIPLY RATE BY 0.56.
APPROXIMATE RADIATION - 60 TO 1.

PROPORTION CONSTANT
HEAT 220° RADIATION 1,00 - 60
" 200° " 1.15 - 52
" 180° " 1.36 - 44
" 160° " 1.66 - 36
" 140° " 2.14 - 28.

HEAT UNITS VALUE.

COAL PER TON	8000	8250	8500	8750	9000	9250	9500	9750	10000	10250	10500	10750	11000	11250	11500	11750	12000	12250	12500	12750	13000	13250	13500	13750	14000	14250	14500	14750	15000	15250
$0.75	26	25	24½	24	23½	23	22½	22	21	20½	20	19½	19	18½	18	17½	17	16½	16	15½	15	14½	14	13½	13	12½	12	11½	11	10
1.00	35	34	33	32½	32	31	30½	30	29	28	27½	27	26	25½	25	24	23½	23	22	21½	21	20	19	18½	17½	17	16½	16	15½	14
1.25	43	42	41½	40	39½	38½	37½	36½	35½	34½	34	33	32	31	30	29	28½	27½	26½	26	25	24	23	22	21	20½	20	19	18	17
1.50	52	51	50	49	48½	47½	46	45	44	43	41½	40	39	38	37	36	35	34	32½	31½	30	29	28	27	26	25	23½	22½	21½	20½
1.75	60	59	58	56½	55½	54½	53	51½	50	49	48	46½	45	44	43	41½	40	39	37½	36	35	34	32½	31	30	29	27½	26	25	24
2.00	66½	66½	65	64	62½	61	60	58½	57	55½	54	53	51½	50	48½	47	46	44½	43	41½	40	38½	37½	36	34½	33	31½	30	29	27½
2.25	76	74½	73	71½	70	68½	67	65½	63½	62½	61	59	57½	56½	54½	53	51½	50	48½	47	45½	44	42	40½	39	37½	36	34½	32½	31
2.50	84	82½	81	79	77½	75½	74½	72½	70½	69	67½	65½	64	62	60½	58½	57	55½	54	52	50½	48½	47	45	43½	42	40	38½	36½	35
2.75	93	91	89	87	85½	83½	80	78	76	74½	72½	70½	68½	66½	65	63	61	59	57	55½	53½	51½	49½	48	46	44	42½	41	40	38½
3.00	101	99	97	95	93	91	89	87	85	83	81	78½	76½	74½	72½	70½	68½	66½	64½	62½	60½	58½	56	54	52	50	48	45½	43½	42
3.25	110	108	106	103½	101½	99	97	94½	92½	90	88	85½	83½	81	79	76½	75	72½	70½	68	66	64	61½	59	57	55	53	50½	48	46
3.50	118	116	114	111	109	106½	104	102	99½	97	94½	92	90	87½	85	92½	80	78	76	73	70½	68½	66½	63½	60½	59	56½	54	51½	49
3.75	126	123½	121½	118½	118½	113½	111	108½	106	103½	101	97½	96	93½	91	88	86	83½	81	78½	76	73½	71	68	66	63½	61	58½	56	53½
4.00	135	132	129½	127	124	121½	118½	116	113½	110½	108	105½	102½	100	97	94½	92	89	86½	83½	81	78½	76	73	70½	68	65	62½	59½	57
4.25	143	140	137½	134½	132	129	126	123	120½	117½	115	112	109	106	103½	100½	97½	95	92	89	86½	83½	80½	78	75	72	69	66	63½	61
4.50	152	149	146	143	140½	137½	134½	131½	128	125	123	119	116	113	110	107	104	101	97½	94½	91½	89	85½	82½	79½	76½	73½	70½	67½	64½
4.75	160	157	154	150½	147½	144½	141½	138	135	131½	128½	125½	122	119	116	112½	109½	106½	103	100	97	93½	90	87	84	81	77½	74	71	68
5.00	168	165	161½	158½	155	152	148½	145½	142	136½	135	132	128½	125	122	118½	115	112	108½	105	102	98½	95	92	88½	85	82	78½	75	72

CONSTANTS

Considering the 50 cent rate and the heat units given out of the radiators, it means about 47 cents per 1,000,000 heat units of efficient heat, which is a little better than 30 cents per square foot of radiation for an inside temperature of 220 degrees. This difference pays for the meter usually furnished by the station manager free of charge. The reasonable equivalent of any rate in a price per square foot and by any method may be found by multiplying the base rate by the constant given in right hand corner of the table, representing the temperature at which heat is furnished inside the radiator.

To show you what this means, assume a building and a charge of $100.00 per season for heat furnished by any method. As different temperatures in the radiator regulate the amount of radiation, it should also regulate the price per foot. In the quantities shown for instance, a charge of 30 cents per foot where 220 degrees is furnished inside the radiator, is the equivalent of 14 cents, if 140 degrees be furnished, there being a corresponding difference in the amount of radiation.

In a table of rates by which buildings may be heated according to the cubical contents and construction, this is also a reasonable equivalent of the base rate referred to; it classifies the buildings and space heated and suggests rates according to the value of the service. For instance, the man who emptied the ashes in the alley would no doubt be perfectly willing to pay you a $12.00 rate for the season's heating, and the man with the frame residence would pay a $5.00 rate for the service rendered him. Those who are using these rates, or charging similar prices, consider them fair and profitable.

TABLE FOR ESTIMATING THE SQ. FT. OF RADIATION IN RELATION TO TEMPERATURE AND THE CU. FT. OF SPACE TO BE HEATED,—WITH TYPICAL CHARGES PER SQ. FT. OF RADIATION.

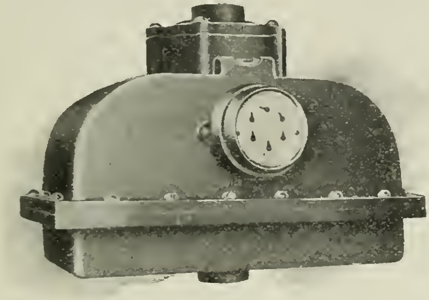
TEMPERATURE WITHIN THE RADIATOR	220°	200°	180°	160°	140°
TEMPERATURE OF THE ROOM	70°	70°	70°	70°	70°
DIFFERENCE OF TEMPERATURE OF RADIATOR AND ROOM	150°	130°	110°	90°	70°
NO OF CU. FT. OF SPACE IN ROOM TO 1 SQ. FT. OF RADIATION	60.00	52.17	44.85	36.14	28.00
PROPORTION OF RADIATION TO CU. FT OF SPACE	1.00	1.15	1.36	1.66	2.14
RELATIVE NO OF SQ FT OF RADIATION IN A TYPICAL HOUSE OF 20,000 CU. FT. CONTENTS.	333.	383.	446.	553.	715.
TYPICAL AND RELATIVE PRICES PER SQ. FT. OF RADIATION	$0.30	$0.26	$0.22	$0.18	$0.14
BASED ON A CHARGE PER YR FOR HEATING A TYPICAL HOUSE, OF	$100.	$100	$100	$100	$100

—RATES FOR CENTRAL STATION HEATING IN DOLLARS PER SEASON PER 1000 CU. FT. OF SPACE.—

	1.	2.	3	4.	5.	8.	10.	15.	20.	30.	40	50	75.	100.	200	300	400	500	750	1000
OFFICE ROOM IN BRICK BUILDING	12.00	11.00	9.50	9.25	9.00	7.50	7.00	6.00												
FLAT ROOM IN BRICK BUILDING	11.00	10.00	8.50	8.00	7.25	5.50	5.25	4.75	4.25	4.00										
STORE ROOM IN BRICK BUILDING	11.50	10.50	9.00	8.00	7.50	5.75	5.50	5.00	4.50	4.00	3.50									
CORNER STORE IN BRICK BUILDING	12.00	11.00	9.50	8.25	7.75	6.00	5.75	5.25	4.75	4.25	3.75									
BRICK BUILDING COMPLETE						4.20	4.13	4.08	4.00	3.98	3.96	3.94	3.90	3.88	3.80	3.65	3.40	3.20	2.90	2.50
OFFICE ROOM IN FRAME BUILDING	13.00	11.50	10.00	9.50	9.25	7.75	7.25	6.25	6.00											
FLAT ROOM IN FRAME BUILDING	11.25	10.25	8.75	8.25	7.50	5.75	5.50	5.00	5.00											
BRICK RESIDENCE						5.50	5.35	5.20	4.85	4.40	4.25									
FRAME RESIDENCE						5.75	5.50	5.25	5.00	4.50	4.30									
WORKSHOP IN BRICK BUILDING						3.75	3.50	3.25	3.15	3.00	2.80									
WORKSHOP IN FRAME BUILDING						4.00	3.75	3.50	3.25	3.15	3.00									
BRICK ASSEMBLY HALL OR CHURCH USED ONE DAY PER WEEK						2.15	2.00	1.75	1.60	1.50	1.45	1.40	1.35	1.30	1.25					
FRAME ASSEMBLY HALL OR CHURCH USED ONE DAY PER WEEK						2.50	2.35	2.00	1.85	1.75	1.65	1.60	1.50	1.45	1.40					

A complete condensation meter can be attached to the drip or return pipe on any form of steam heating. It measures the volume of water passing through it, registering one pound for each $27\frac{6}{10}$ cubic inches, this being the average volume of one pound of water pumped into the plant to be manufactured into steam. In operation it is simple, consisting of a poised tank, having two compartments arranged so that as soon as one side has its quota, it tips and empties, while the other side fills. It may be adjusted to suit the volume equal to the temperature at which it may be required to weigh. It operates without pressure, and it matters not if the condensation comes to it in spots, dribbles, or gushes; its duty is always performed.

The average temperature in this locality during the heating season is about 35 degrees; buildings are usually heated with an amount of radiation that will keep the room at 70 degrees in zero weather, therefore, any system, either of metering the heat used, or heat regulation, is a big saving to the heating plant, as compared with the practice of past years, and even that of some good money-making plants of today.



Meter for Water of Condensation.

There are a number of heat regulating devices. Probably the plan meeting with most favor at present is to operate a diaphragm controlling valve at the building by air pressure furnished from the central station, the controlling valve being set in operation by a thermostat in a similar manner to that seen in offices and other buildings.

The value of exhaust steam from a lighting plant is a variable quantity, depending upon the amount available. It is not the purpose of this paper to present data from some particular plant, or the writer could show you an instance in which a large quantity of exhaust steam being available and other favorable conditions, had netted the station a clear gain of $18,000.00 last year. Such cases are not fair samples, but as considerable is being said about the value of exhaust steam, your attention is called to a paper by A. W. Ritchie and B. S. Swenson, read before this society on September 6th, 1900, which, in dealing in the efficiencies of electric lighting plants, gives (as others have) the percentage value of heat in exhaust after heating the feed water, at approximately 50 per cent of the value of the coal. Therefore, assuming an electric light plant, having a coal bill of $10,000 per year, the value of the exhaust for 200 days would be $5,480 less 50 per cent due to the inability to utilize it at the time of delivery. This makes it $2,740, or in round numbers 27 per cent of the coal bill at the electric plant, or 18 per cent of the coal bill at the heating plant. Assuming this heat to be utilized in a central station heating plant, having a coal bill of $15,000 per year, it would save 18 per cent. In order to use it, however, the size of the mains must be increased which means added loss in transmission, so that it is questionable if in all cases there is any economy.

By this time you have formulated in your minds some idea as to proper business methods, the cost of heat manufactured at the station; the cost if manufactured by the customer; the difficulties to be encountered; the character of the apparatus preferable to use for transmission; the rate of charge and the value of exhaust steam. In formulating an idea as to the method best to employ, the things to be considered are:

First. The cost of mains, which is (assuming first class construction) from $2.00 to $20.00 per foot, according to size. A 10-inch main for direct steam costing in all, say, $7.00 per foot. This would also apply to mains of the same size, using exhaust steam. For an induced circulation method, then, 135 per cent of the amount, and for hot water, 165 per cent of the amount, on account of the additional or return pipes.

Second. The carrying capacity of the mains in heat units, which is dependent upon the velocity at which the medium travels, its volume and heat units contained.

Third. The loss in transmission due to the inefficiency of insulation, and distance traveled in going and returning.

Fourth. Loss of heat units to the sewer, if unused heat be not returned, from draining the condensation into the sewers.

Fifth. Loss in traps and devices used to induce circulation.

Sixth. Loss in regulation, due to imperfect control of heat, whereby the heat furnished is greater than that required to do the work with due consideration of the outside temperature.

Seventh. The credit value of exhaust steam.

Eighth. The credit value of heat units returned to the station.

To determine these qualities precisely, as is sometimes done in tests of engines, would require observations each hour for 200 days, at each building, owing to the almost hourly variation in temperature. As stated, the writer knows of no such tests having been made; neither does he know of any standard rule applicable to all, that is reliable. Observations, however, have been made by the writer and intelligent station managers, such for instance, as a determination of the loss in transmission by placing thermometers or guages at different points in the mains, also trapping and weighing condensation; observing the average temperature and quantity of condensation passing to the sewer; observing the difference between the amount of heat used in buildings where heat is simply turned on, in comparison with the amount used or sold by meter to the same customer; observing the loss through single traps placed on a steam main and connected with a vacuum pump;

observing the quantity and temperature at which, after the return vapors or steam together with condensation has been through the condenser of the pump, is given back to the boiler for reheating; observing the amount, cost and quality of the coal used to perform the duty required; observing and estimating the duty by weighing condensation in typical buildings; all these observations analyzed in connection with the receipts are a simple method whereby results may be reasonably judged and deficiencies located.

In order to convey a fair idea of the heat carrying capacity, losses, advantages and disadvantages under which stations using different methods are practically operated, a set of tabulated observations are submitted in which for the purpose of comparison, the cost and selling price of heat is the same.

OBSERVATIONS IN OPERATION OF TYPICAL HEATING PLANTS.

	1.	2.	3.	4.
	DIRECT STEAM	LIVE AND EXHAUST	INDUCED CIRCULATION	HOT WATER
SIZE OF INITIAL MAIN	ONE 10"	ONE 10"	ONE 10" AND ONE 3"	TWO 10"
PRESSURE IN POUNDS PER SQ. IN	40	5.	ATMOSPHERIC	60
VOLUME OF 1 POUND PER CU. FT	7.36	19.91	26.6	27.8
VELOCITY IN FEET PER SECOND	275.	200.	500.	525.
POUNDS OF WATER PER SECOND	20.32	5.46	10.23	286.6
POUNDS OF WATER PER MINUTE	1219.2	327.6	613.8	1719.6
HEAT UNITS PER POUND (FROM AND TO)	1150.-50° TO 40°	1132-50° TO 5°	1128. 50° TO A	20. 160° TO 180°
HEAT UNITS PER MINUTE	1,402,080.	370,843.	692,366.	343,920.
LOSS IN TRANSMISSION-IN B T U PER MIN	112,166. 8%	55,625. 15%	83,083 12%	106,152. 31%
LOSS TO SEWER " " " "	70,104. 5%	18,542. 5%	NONE	34,392. LEAKAGE OF 10%
LOSS BY REGULATION " " " "	98,145. 7%	26,959. 7%	48,465. 7%	24,064. 7%
LOSS THROUGH TRAPS " " " ".	14,020. 1%	7,416. 2%	103,854. 15%	NONE
TOTAL LOSS " " " ".	294,435. 21%	108,542. 29%	235,402. 25%	164,608. 48%
EFFICIENT HEAT UNITS	1,107, 645.	262,301.	456,964.	179,312.
B T U PER AVERAGE CUSTOMER PER MINUTE FROM ZERO TO 70°	1,575.	1575.	1575.	787.5 AVE. TEMP.
NO. OF CUSTOMERS	403.	180.	260	227
CUBIC FEET OF SPACE HEATED	14,763,000.	3,486,000.	6,080,000	4,767,000.
RELATIVE COST PER FOOT OF MAINS	100.%	100 %	135 %	100 %
RECEIVED FOR HEAT AT 47 CTS PER 1000,000 B.T.U	$ 0.52	$ 0.123	$ 0.2147	$ 0.084
CREDIT VALUE OF EXHAUST-18% OF HEAT MADE		66,751.	124,625.	
CREDIT VALUE OF RETURNED HEAT UNITS			122,760.	
ACTUAL HEAT UNITS PRODUCED	1,402,080.	304,092.	444,981.	343,920.
COST OF PRODUCTION AT 16 CTS PER 1,000,000 B T U	$ 0.2341	$ 0.0486	$ 0.071	$ .055
INTEREST AND COST OF OPERATION	$ 0.04	$ 0.025	$ 0.042	$ .03
TOTAL COST OF OPERATION	$ 0.2741	$ 0.0736	$ 0.113	$ 0.085
PERCENTAGE OF PROFIT	49.	41.	48.5	LOSS

HOT WATER TEMPERATURES		
OUTSIDE ATMOSPHERE	OUTGOING WATER	HEAT USED BY ONE CUSTOMER
70°		B.T.U.
60°	120°	225
50°	140°	450
40°	150°	675
30°	160°	900
20°	180°	1125
10°	190°	1350
ZERO	200°	1575
−10°	212°	1800

You will notice that in each a 10-inch main is used; numbers 1, 2, and 4 are from plants in operation observed by the writer with information from the managers. As it is almost impossible to find plants similar in conditions, some explanation is necessary. First, No. 1 carries a higher pressure than is usual. The manager rightly argues that high pressure means increased velocity, low volume and increased heat units. Consequently as the transmission loss in any given form of insulation is practically constant, he gets a greater efficiency. Note the total losses, the loss to the sewers, etc., the space heated and the percentage of profit, which of course does not take into account interest and other business charges. It is given in each case, however, for a comparison.

No. 2 uses exhaust and carries five pounds pressure. These mains are not as long, in fact a smaller plant but necessarily a 10-inch main on account of the increased volume. Note the credit of 18 per cent for exhaust steam used; a total loss of 29 per cent, space heated, and percentage of profit.

Passing to No. 4, a hot water plant. Information and observation were meager. Note the space heated, credit for exhaust steam, the loss in transmission due to two pipes, low temperature, and possibly poor insulation. It does not seem to be making money. Note the comparison of heat units, capacity in each of the four cases, it is interesting as an illustration of the capacity of pipes under different conditions Note that one pound of water carries only 20 heat units. The table at the right is the variation of temperature of the hot water going out, relative to the temperature of the atmosphere, and the probable heat units used by a typical customer, under varying conditions, if his house cost to heat about $100.00 worth of coal, as shown in previous illustrations. The writer is informed that there are a number of similar plants making money; therefore, if his observations are unfavorable, it is for the want of personal knowledge. In any event, we desire to see this plant a success and the suggestion may be a good one that in view of what No. 1 is doing, if No. 4 will raise the outgoing temperature to twice the amount, he will have the same losses but the *percentage* of loss will be less, also reduce the temperature of the return, and the main will become that much more efficient. To double the amount of heat transmitted, means doubling the capacity, efficiency, and revenue. If his mains will not stand the strain, they should be improved.

Having called your attention to induced circulation, this paper would not be complete unless it gave some intimation of its possibilities. Therefore in explanation of No. 3, I will say that it is not based on a station in operation as others are. Observations, as I have already explained, have been made of the efficiency of traps and the value of return heat; therefore, with the known volume and heat units value of one pound of steam at atmosphere, the velocity being assumed, the illustration is given to show a reasonable comparison. You will note that as there are two pipes (10-in. and 3-in.), it has added a loss in transmission. On the other hand, there is increased velocity and returned heat units to be credited. Its application, however, should be a judicious one.

A few months ago the writer was asked to formulate a set of questions by parties investigating the subject of heating, the intention being to find out direct from those operating plants what was the state of the art, and if in *their* opinion heating from a central station was a success. These questions were sent to stations of all kinds, and replies were received from about one half of those questioned. It was found that out of the replies received (excepting of course, those that were vague) about an equal number were from stations using direct steam, live and exhaust, and hot water. For the purpose of this paper, the writer has permission to use this information, which is tabulated, and necessarily simplified from some of the original replies to yes or no; he has also withheld the names as not being proper to the exhibit; also the cause of difficulty when it occurred. The prosperous ones, however, seemed to have very little trouble. In presenting this tabulation, which is typical of others, the writer would say that the original replies are in his possession, and from which the figures may be verified.

—— REPORTS ON OPERATION OF CENTRAL STATION HEATING PLANTS.

	1.	2	3	4	5	6.	7.	8	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.
DO YOU USE LIVE STEAM ONLY?	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES							
DO YOU USE EXHAUST STEAM ONLY?	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
IS IT PROFITABLE?	YES	YES		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
DO YOU USE HOT WATER?													YES	YES	YES	YES	YES	YES	YES
WHAT IS YOUR PRESSURE IN MAINS?	15 TO 20	4 TO 8	35	50	5 TO 28	5 TO 20	3 TO 5	2½ TO 15	5	5	2 TO 6	1 TO 6	50	55	60	40 TO 50	30 TO 50		60
HOW MANY FEET OF MAINS HAVE YOU?	7000'	4930	4 MI	4500'	11500	15600'	3000'	12000'	3000'	7790'	5900'	10000'	1 MI.	6 MI	3 MI	20000'	5 MI	1200'	
WHAT IS THE SIZE OF YOUR INITIAL MAIN?	12"	8"	10"	12"	10"	10"	8"	12"	8"	10"	12"	14"	8"	8"	8"	8"	12"	8"	10"
HOW MANY MILLION CU. FT. OF SPACE CAN YOU HEAT?	20		30	30	10	10		10		8	12		1.5	3	1.5			1	1
HOW MANY CUSTOMERS HAVE YOU?	82	53	500	600	330	300	28	350	35	150	130	275	100	165	78	100	200	100.	
ARE YOUR CUSTOMERS GENERALLY SATISFIED?	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
WHAT IS YOUR METER RATE PER 1000 LBS.?	.60	.50	4.66 FLAT		4.95 FLAT	FLAT		5.00 FLAT	.50	.60	.60	.50							
WHAT IS YOUR METER RATE PER SQUARE FOOT OF RADIATION?				0.30			0.25			.25-.30	0.30	0.27	0.15	.12½-.20	0.15	0.15	0.18	[illegible]-.20	0.18
WHAT IS THE COST OF COAL DELIVERED?	1.25	4.00	2.30	1.19	3.55	2.79	1.50	1.25	WOOD 1.75 C	1.60	2.50	1.30	1.50	2.00	2.15	1.29	1.10	1.85	
WHAT IS THE FORM OF YOUR CONTRACTS?	COPY		COPY			COPY	COPY	COPY	COPY	COPY	COPY	COPY	COPY						COPY
ARE HEAT REGULATORS PRACTICABLE?	YES			NO				NO		NO				NO	YES	YES	NO	NO	
WHAT KIND OF BOILERS DO YOU USE?	WT	RT	RT	RT	WT	RT			WT	WT		RT	W.T	WT	WT			W.T.	
DO YOU USE ECONOMIZERS OR STOKERS?	YES	YES	YES	NO	NO	YES		YES	YES	YES	YES	NO	NO	NO		NO			
WHAT IS THE AVERAGE DEPTH OF MAINS?	5'	5'	8'	6'	6'		8'	5½'	5'	5'	6'	4½'	4'	3'	3½'	3½'	2½'	2'	3'
HOW FAR APART ARE YOUR EXPANSION JOINTS?	50'	100'	50'	50' & 100'	100'	50'	50'	100'	100'	100'	50'		700'	400'	400'		500'	500'	300'
DO YOU BREAK INSULATION IN CONNECTING?	NO	NO	NO	NO	YES	NO	NO	NO	NO	NO	NO		YES	YES	YES		YES	YES	YES
DO YOU USE COPPER OR RUBBER GASKETS?	C	C	C	C OR R	C	C	C	C	C	C	C		R	R	LEAD		R	R	C
DO YOU HAVE LEAKAGE IN JOINTS OR MAINS?	NO	NO	SOME	SOME	SOME	SOME	NO	SOME	NO		NO		YES	SOME	NO		YES	YES	NO
WHAT IS THE PERCENTAGE OF LOSS PER MILE?	3	4 TO 15		5				20	2	6 TO 15			[illegible]		2				
DO YOU FAVOR COMBINED HEATING AND POWER PLANTS?	NO	YES				NO	YES		YES	YES	YES		YES	YES	YES			YES	
DO YOU RAISE WATER OR STEAM?	S	S	S	S	S	S	S	S	S	S	S		W	HTW	HTW			W.	W
DO YOU FAVOR COMBINING LIVE AND EXHAUST STEAM?	YES	YES			POSSIBLY	YES		YES	YES	YES	YES	YES							
DO YOU FAVOR RETURNING CONDENSATION?	NO				NO		YES	NO			YES								
WHAT OUGHT TO BE THE PERCENTAGE OF PROFIT?	10	12	33⅓	33⅓	2 TO 14	50	25	12	15	50	33	33	15			6	6	18 TO [illegible]	
WHAT ARE REMUNERATIVE RATES FOR 1000 LBS.?	$0.60	$0.50	$0.48	$0.53	$0.5		$0.41		$0.50		[illegible] TO .60	$0.50	$0.20	$0.25		$0.22	$0.22		

From what has been said you will no doubt be able to analyze this interesting report yourselves. Your attention is called, however, to the figures given, as indicating the percentage of profit in the business. The writer desires to say that these stations are not all equipped or operated in the best manner possible, yet a majority are profitable.

In conclusion, the writer expresses the opinion that, under the direction of good engineering advice, the business of heating from a central station will improve, and the hope that this paper has given you reasonable grounds for believing that heating from a central station is a success when proper methods of business, with good engineering and apparatus are used.

DISCUSSION.

Mr. R. L. Gifford—In regard to the method employed in arriving at the value of exhaust steam which is given in table as 18 per cent. If I remember correctly, it was deduced from a single illustration wherein they had exhaust steam of a value of $2,750.00 a year, and a large amount of live steam was necessary to carry the heating load. In that case the exhaust steam was 18 per cent of the total, but this would not be true of other plants.

Mr. Pearce—I gave these figures simply to show what is sometimes realized in practice, and also to show notwithstanding that the cost of exhaust steam might be 90 per cent of the cost of the coal, its actual value under the conditions mentioned would be 18 per cent of the cost of coal to the heating plant, although, as I have stated, there were instances where its value was much higher.

Mr. Gifford—Of course that is entirely dependent on the relative amount of exhaust steam available, or the proportion of the exhaust to live steam required. Take the average plant—the heat units available for heating in the exhaust steam are certainly 85 per cent of the heat units available in the same horse power of live steam, so that, as a general proposition, I think 18 per cent, as a value of heat units in exhaust steam, is entirely too low, I think 85 per cent would be nearer right, because in a majority of plants where engines are run non-condensing there is enough exhaust to do the heating.

Mr. Pearce—We must bear in mind first, that the efficiency of the boiler is say, 70 per cent. Deduct from this the heat used by the engine and that required to heat the feed water, then as shown by the authorities quoted, the actual heat value of the exhaust is but 55 per cent of that of the coal. Now consider that you utilize this but 200 out of the 365 days and make due allowance for waste, and you will find the actual money value of the exhaust in the case shown is substantially 18 per cent of the coal bill.

Mr. Gifford—If we have an induced return or vacuum system, so that back pressure is eliminated from the engine supplying the exhaust, that is, so that this exhaust steam is circulating without any resultant loss in the power production, the exhaust steam is equal to, say, 85 per cent of an equal horse power or quantity of live steam.

In a great many plants there is exhaust steam available to carry the heating load, and where that steam is circulated without back pressure and all the condensation is brought back to the boilers, you are getting your heat as a by-product.

Of course it is self evident that the exhaust steam is not used for heating all the year round, but that does not affect the per cent of heating value of the exhaust as compared with an equal amount of live steam.

Mr. Pearce—I grant that 80 or 85 per cent may be the heat units value of the exhaust, and that it cost 80 or 85 per cent of the coal bill to produce; what the paper intends to show is that the *value* to the heating plant of that portion which is utilized by the heating station in the illustration given is but 18 per cent of the total coal bill of the heating plant.

George Wellsby Scott (by letter)—While Mr. Pearce has spoken at length upon the subject of his paper, there are several points concerning which further information would be valuable, and in this connection I would ask the following questions:

(A) What is the greatest continuous length of planked conduit construction similar to, say, No. 9, in successful service today?

(B) How many years has it been in service?

(C) What is its present condition?

(D) When opening up the form of conduit shown in No. 9, say, for the purpose of making additional connections to the main, or for changing connections already in place, what is the preferred method adopted to prevent the collapse of the structure? Also, what course is pursued to insure the proper replacement of the successive layers and make good the end joints of the boards? In asking these questions I assume the boards to break joint in their lengths. If however, they do not, will Mr. Pearce please describe the most approved method with respect to arranging and closing the joints at the ends of unit lengths?

(E) How are the joints in the main conduit (Fig. 9) formed with respect to the junction of lateral conduits? I am not referring to the principal lateral connections made at fixed and anchored points in the main, but to parts between such fixed points?

(F) With respect to the practice of measuring the amount of water of condensation as indicating the value of the service rendered: Is it not a fact that such a method would suffer by reason of a less favorably located branch or lateral carrying more entrained water than a more favorably located one?

In his reference to exhaust steam heating Mr. Pearce states that, compared with live steam mains, larger mains would be required for an equivalent service and that this would involve added losses in transmission; and he questions if, after all, there is any resulting economy in the use of exhaust steam. The author may have most excellent grounds for this conclusion; but I scarcely think he would care to have this expression understood as being applicable in general. If he does, I would like to ask if he means that having exhaust steam available he would discard it in favor of live steam for heating purposes?

But the advantages in favor of exhaust steam heating are so many as to leave no doubt concerning the economical results attending its application and use. In the first place, the very consideration of exhaust steam necessarily implies the fact of a prior use having been made of the steam, and, hence, whatever further use can be made of this exhaust or waste steam may he had free of charge save for the comparatively small item of cost for its operation.

Mr. Pearce has referred to a central heating station in association with an electric lighting plant, and such a plant may be considered with reference to the following remarks: Other things being equal, it is plain that with respect to the production of electricity some form of compound condensing engine would be the most desirable. Such an engine would cost more than a simple or even compound non-condensing engine, and its condensing apparatus would occupy space not required in the case of the non-condensing engine. Its efficiency, or degree of economy would, however, be, say, 20 to 25 per cent higher than that of the non-condensing engine, and to this extent there would be a direct advantage in favor of the condensing engine. The final monetary advantage is, however, dependent upon the several values of prime cost, interest operation and depreciation.

Cleared of incidental figures, it may be taken as being close to the truth that if a compound condensing engine of, say, 2,000 H. P., uses 30,000 pounds of steam per hour, then a non-condensing engine of equal horse power would use 36,000 pounds of steam per hour. At this stage it would appear as if the advantage were with respect to the condensing engine; but our consideration is to include as associated a steam heating installation, and it is here that the advantage passes from the condensing to the non-condensing equipment by virtue of the ability to use exhaust steam in the heating system.

To preserve the simplicity of this consideration let it be assumed that the steam heating system requires 36,000 pounds of steam per hour. Now if the equipment is to be that of the condensing engine outfit, it is clear that the total amount of steam required per hour will be 30,000 pounds for the electrical work and 36,000 pounds for the heating work, or 66,000 pounds of steam, in all, per hour. On the other hand, it can be shown that exhaust steam even at the pressure of the atmosphere has a heating value of 98.5 per cent, compared with steam at a pressure of about 20 pounds per square inch, and even a value of 97.6 per cent compared with steam at a pressure of about 40 pounds per square inch above the atmosphere. While it is true that to successfully operate an exhaust heating system, especially one applied over a large area, requires some form of mechanical means for inducing the flow of steam, and that such apparatus will require power for its operation, yet the cost of such power is not at all prohibitive. And if, as it may be, a steam pump is used, then the steam for its operation can in turn be exhausted into the heating main, and thus be available for further duty with the exhaust steam from the engine for heating purposes. Making due allowances for loss of heat, operation and leakage, I would place the value of the exhaust steam available for heating at 90 per cent of the live steam value.

Hence, if 36,000 pounds of steam per hour be required for the heating system, and there be available for heating purposes the equivalent of 90 per cent of the 36,000 pounds of steam used by the engine, then there would be required only 10 per cent of additional steam to supply the full requirements of 36,000 pounds per hour. In other words, the steam required per hour would be 36,000 pounds for the engine, plus 10 per cent, equal to 3,600 pounds per hour for the loss referred to above; or a total quantity of 39,600 pounds of steam per hour. But the other installation using a condensing engine for power and live steam for heating purposes, requires 66,000 pounds of steam per hour, or 66.66 per cent more than is required in the installation using a non-condensing engine for power and exhaust steam for heating.

But while this is a direct showing in favor of the exhaust steam heating system, there is yet another feature in this consideration which is worthy of more than passing attention, namely: that in the installation using exhaust steam and returning the water of condensation to the boilers, the water so returned would have a temperature of about 188 degrees Fahrenheit; whereas in the case of the condensing engine plant the water available from the hot well for feeding the boilers would have a temperature of about 110 degrees Fahrenheit. Taking due account of this temperature difference in connection with the respective quantities of steam concerned, would give a result showing that the cost of fuel in the case of the condensing engine plant would be 75 per cent greater than in the case of the non-condensing engine plant using exhaust steam for heating.

Nor is this advantage necessarily limited to the heating season; on the contrary there are few heating installations which may not be used with profit all the year round. In this connection I may mention the very common application of heating water for household uses, and for numerous other purposes within the operating territory of the system; and upon the extent of the service rendered will depend the final value, or economical result.

But quite apart from this consideration is the demonstration in the domain of applied science; and in this connection I may refer to the enormous reductions in operative costs brought about under the writer's direction by the extensive use of exhaust steam in the large works of the Pullman Company, at Pullman, Ill. The writer is now conducting similar economic work in the extensive premises of Parke, Davis & Co., Detroit, Mich., and within the past few months has demonstrated, in the case of a manufacturing plant, a reduction in coal bills from $24,724 per year to $20,895 per year, or a saving of $3,839 per year by the use of exhaust steam. In this particular case it should be noted that the process involved the change from condensing to non-condensing; furthermore, that the item of steam for heating buildings was by no means the largest one involved. The writer might continue with references of this character, but only to show, case after case, that where steam heating is required for temperatures below 200 degrees Fahrenheit there can be no question regarding the economical results attending the use of exhaust steam, where available.

Here, also, it may be claimed that this practice is not typical of central station heating work; but such a claim, if made, could not well be sustained; for if central station heating is to be held as limited to warming houses and stores in winter, then so much the worse for the company. As a matter of fact, progressive central station heating companies are reaching out much in the lines herein referred to, and with the fixed intent of operating their heating mains all the year round.

There is another point in Mr. Pearce's paper to which attention should be directed, and that is the allusion made to trapping the water of condensation to the sewers. While it is not stated that this practice is referred to by Mr. Pearce as meeting with either his approval or disapproval, I am reasonably sure that he will not wish the impression to be gained that it is anything but a wasteful process and inadmissible under proper circumstances. That it is wasteful of heat, and thus of coal, is self-evident, seeing that the water may have a temperature not far below 200 degrees Fahrenheit. But even more than this is the fact of the water itself being wasted; for it should be understood that this is water of condensation, practically distilled water, and thus free from incrustating and deleterious elements either in combination or suspension. It is an ideal water for boilers, and that it should be permitted to go to waste is evidence of a condition needing economical treatment.

Compare this wasteful practice with the highly efficient and thoroughly economical system of heating by exhaust steam. In this system in which the radiators and coils are doubly useful in that they at once serve as heating appliances and also as condensers from which the condensation water passes—not into a sewer but into a return main, which conducts it back to the power plant and delivers it with all its heat and purity into the boilers. These once more convert it into steam to be passed out to do useful work in some live-steam apparatus; then again, as exhaust steam, to go on its mission of heating; the cycle is repeated indefinitely.

CLOSURE.

Mr. Pearce—Replying to Mr. Scott's questions regarding the planked form of casing, illustrated in No. 9, this has already been described as being lined with tin and asbestos, machined and fitted woodwork, felt between the woodwork, and covered with asphalt pitch on the outside. It is usually made in eight foot sections. Its general construction, therefore, does not differ materially from casing No. 4, excepting that it has vertical sides; in this respect it is similar to casings Nos. 7 and 8, No. 7 being described as having vertical sides. This is to give support to the top, so that the tendency to open at the joints would be counteracted, while in No. 4 (as in others) the casing is bound with wire bands for the same purpose. This tendency to open at the joints is the thing to be overcome in all of the better class of casings, and not a tendency to collapse as intimated. Indeed, the sketch shows for itself, as others do, that it could not possibly occur in either this or any of the better forms of construction. The sections have mortise and tenon joints at the end, driven together with a maul and the interstices filled with asphalt pitch.

This particular construction has recently been placed upon the market. Its years of service could not be a proper indication of its value to an engineer for central station heating, but of value rather is its design and construction to overcome the known difficulties to be met, and for this purpose the illustrations are given. It is fair to presume, however, that when properly laid with sufficient under-drainage, its life would be at least equal to that of other forms of wood construction installed in like manner. As an instance of the life of such casings, one was recently taken up in Milwaukee that had lain in the ground some twenty years and the engineer in charge said that its condition was such that neither the pipe nor the casing could be distinguished from new material. This also suggests the desirability of proper ventilation, a thorough coating of moisture preventative on the outside, proper under-drainage, and the pipe itself allowed to operate freely inside without any form of insulating material coming in contact with it, as such may corrode the pipe. The greatest continuous length of this construction I am unable to give. It is fair to presume, however, that the older forms of casings would make a much better showing in this respect, owing to the fact that the districts heated have usually been added to from year to year. The present condition of this casing placed underground for the purpose of test fully meets what may reasonably be expected from the design shown.

In regard to joints made in the main conduit, the undesirability of this form of construction has been shown, as also the old and unsuccessful practice of making connections by breaking the insulation, as it is a source of loss. The more modern methods arrange the connections to be made, for any and all purposes, at practically fixed points, and this is accomplished by making the fitting of such character as to serve the combined purpose of connections, expansion joints, anchors, water separators, etc. You will observe in the tabulated statement of reports of operations of central station heating plants generally, that the most successful operators state that their construction is such that "they do not break the insulation" in making the connections referred to, and all connections are made from practically fixed points.

It has already been shown that in proper forms of construction, the fittings used form a continuous line of water separators. It is also proper in laying out mains, to make such arrangements as to equalize the flow. If this practice is followed and the circulation properly proportioned, the tendency for entrained water to collect at any one point is practically obviated. This has already been suggested in calling attention to the results of waterhammer in pipes laid underground. Therefore, in the application of a meter for the purpose of measuring condensation it would not suffer. But even should there be a tendency in the direction indicated, you will notice that is adjusted to register 1 pound for each 27.6 cubic inches, equivalent to 1 pound of water pumped into the plant, and that for any variation in this, either in volume or heat units that the condensation may represent, it may be easily adjusted to suit the requirements.

Answering Mr. Scott's remarks in connection with the use of exhaust steam, it should be borne in mind that the paper read was intended to give a comprehensive idea of central station heating, exhaust steam being used in three of the four methods tabulated. Therefore, unless an unreasonable amount of time be consumed in showing its value under different conditions, some general statement should be made conveying a general idea of its value which would apply to all methods of heating. The paper stated that "the value of exhaust steam from a lighting plant was of variable quantity depending upon the amount available." For instance, in mild weather with the heating plant in operation and but a small amount of the exhaust steam being used, its value to the heating system would not be 90 per cent of the value of live steam to the heating plant, as the greater part would under the conditions, be wasted to the atmosphere. A curve representing the variations in quantity and time of delivery of exhaust steam to a heating plant, and a similar curve representing the demands of the heating plant for the exhaust, will show that at times the exhaust would be in excess and wasted to the atmosphere and at other times it would not be sufficient. There are no two set of conditions alike, and it was therefore proper for the writer to assume a typical plant. In doing so, instead of placing the value of exhaust steam at 90 per cent of the cost of live steam, it is expressed as approximately 50 per cent of the heat units value of the coal. Hence there is a substantial agreement as to the actual value of exhaust steam when there is taken into consideration, that an engine uses but 8 per cent of the heat delivered to it. I do not suppose that Mr. Scott intends to express the idea that if an intelligent engineer had to install a plant for both power and heating service that the proposition would be considered from divided standpoints, but on the contrary, it would properly be considered as a whole. In which case the simple engine would be usually selected. Nor do I presume he wishes to have it understood that the actual cost of producing power in typical plants operating under various conditions of heating and power loads is an additional 10 per cent over and above the cost of coal for heating service only. If so, it would be an easy matter to prove the theory of those to whom the paper refers as able to show that "power is a by-product of a heating plant," as it would only need the revenue derived from the sale of ashes used in the construction of cement sidewalks to round out the assertion. On the contrary, Mr. Scott gives us practical examples of a manufacturing plant in which he demonstrates a saving of $3,829 per year on a previous coal bill, for power only, of $24,724 by the use of exhaust steam, or, in round figures, 14 per cent. While this showing is not as good as the 18 per cent stated in this paper, it substantiates the illustration as a reasonable and fair proposition. It might be added however, that in view of many other uses to which steam can be applied in a manufacturing plant, this showing of 14 per cent would usually be much higher. In reference to this manufacturing plant, that on the presumption the changes referred to might have cost $20,000, there would be an item of interest of $1,000 which would further reduce the actual saving.

The illustrations of a return system of piping for underground work, represent recent designs patented by me. This is evidence of my confidence in exhaust steam for heating, but as already stated in my paper "its application should be a judicious one," and in view of the evidence showing past methods of utilizing it, the further statement in the paper still holds good that "it is questionable if in all cases there is resultant economy."

As to the size of mains required for utilizing exhaust steam that is, as has been illustrated, simply a question of the heat transmitting capacity of the mains used, which is dependent upon the volume, and velocity attained. In the examples given these differences may be noted, together with the statements of operators using live steam only and those using live and exhaust. It will be found that the amount of space heated in these two examples differs very materially, and it is also self evident that, even with the same velocity, the volume of exhaust being so much greater than that of live steam, in the instances cited by the paper, the pipes must necessarily be larger to transmit the same heat units.

The paper was not intended to deal with isolated heating plants, one of the reasons given being that "the loss from traps and other devices in such a plant would not be a lost product to the building to be heated." These losses from the apparatus itself being within the building, the building must receive and be benefited by the heat, whether it comes directly from the radiator, the main line or the return line. If a power and heating plant used in connection with a manufacturing institution—such, for instance, as the Parke-Davis plant—be placed in an adjacent though separate building, the losses in transmission from the underground mains would only be nominal, as from the drawings exhibited to the writer, these mains in all, are but a few hundred feet in length. Such a plant Mr. Scott must have had in mind, when the allowance he makes for loss of heat, operation of engine and leakage is placed at 10 per cent. This class of plant rightly belong to that class that has been designated as generating the heat within the building and is not referred to in the paper under discussion. If Mr. Scott will take into consideration the losses in transmission as set forth, then the actual value of either live or exhaust steam delivered at the building to be heated will be found to be entirely different from that mentioned.

Mr. Scott speaks of the return of condensation, and seems to give the impression that this condition is peculiar to plants using induced circulation, which is not necessarily true. In the instance mentioned in the paper where the use of exhaust steam had netted the owner of the plant some $18,000 last year, the condensation was returned to the boilers without the use of a pump. The territory heated was over a large area, and otherwise fulfilled the requirements as outlined. I doubt very much if any further economical results could be obtained, owing to the peculiar conditions attending its operation. Instances of this character are numerous. The Rookery Building, Chicago, is now operated practically without back pressure, furnishing both light and heat, the pipes being of sufficient size to give free opportunity to the flow of steam. The engineer in charge states they have received many overtures from those installing pumps and other devices, but have failed so far in getting any guarantee of better results than they are now obtaining. This building probably gets much better results from the use of exhaust steam than either the typical plant illustrated in the paper or the maufacturing plant described by Mr. Scott, for during the heating season they utilize at all times all that the engines will furnish, and in addition are obliged to use a quantity of live steam. Condensation is returned to the boilers, and in fact everything accomplished that could be attained with a pump, except decreasing the size of their pipes.

I do not understand that any good engineer doubts the benefits to be derived from the use of exhaust steam in manufacturing plants. The real objection to its use is the fact that from continual growth and the addition of new buildings the demand on the main supply pipes for additional service has many times brought about a back pressure on the engine, necessitating the use of live steam instead of exhaust and eventually the reorganization of the heating system. In order that the exhaust may be used without back pressure, the proper application of a pump, such as has been done at Pullman, would no doubt show a decided advantage, as compared with the plan using back pressure, as the back pressure on the engine would be changed to effective work in the heating mains. That the same results might in some cases also be accomplished without the pump is already shown. The reduced cost for mains would be another consideration for putting in the pump.

Mr. Scott speaks of the use of steam for household purposes in addition to that of heating the buildings, and states that there are very few plants in which it may not be used with profit the year around. This class of work is already being done in the heating season, and assume that it represents 5 per cent of the total work done, then considering the transmission losses, which are practically constant, it will be seen that unless exhaust steam is available in quantity and at all times, the losses would be much greater than the revenue derived in the summer time. Those who have tried this sort of thing have come to the conclusion that the charge for such service must be at least $2.00 per thousand pounds of condensation in order to make it pay. The result of experience shows that, generally speaking, the heating of water for household purposes is not a financial success.

In reference to the trapping of water of condensation to sewers, this is peculiar to a live-steam heating plant, but that it is a wasteful process no one doubts. It is also true that the generation of power from coal is a decidedly more wasteful process. There are losses in all methods of heating; the question is: Which shows the least? I do not think that this waste is inadmissible under proper circumstances. In the illustration given, full credit for the return of condensation or charge for the waste of water to the sewer has been made. The question of final results is what decides the issue.

Another object of the paper under discussion was for the purpose of pointing out the cause of loss in the various methods, without special reference to any one. The statement was made however, that the writer believed that notwithstanding the loss or gain that might be peculiar to any one (and in fact the very poor showing made by some) each method has its proper place and I would also add that in central station heating the question of the present time is not entirely one of method, but also one of man and devices. It remains for the intelligent engineer, who is not confined to one idea, to make such application of any method as the circumstances and conditions in each case may demand. Success in future central station work will be attained by those who, acknowledging past failures are equipped not only with experience, but also with apparatus designed to minimize the losses shown to exist in any method.

THE GRAPHICAL CALCULATION OF FLANGE STRESSES IN GIRDERS AND TRUSSES

By Oscar Sanne, M. W. S. E.

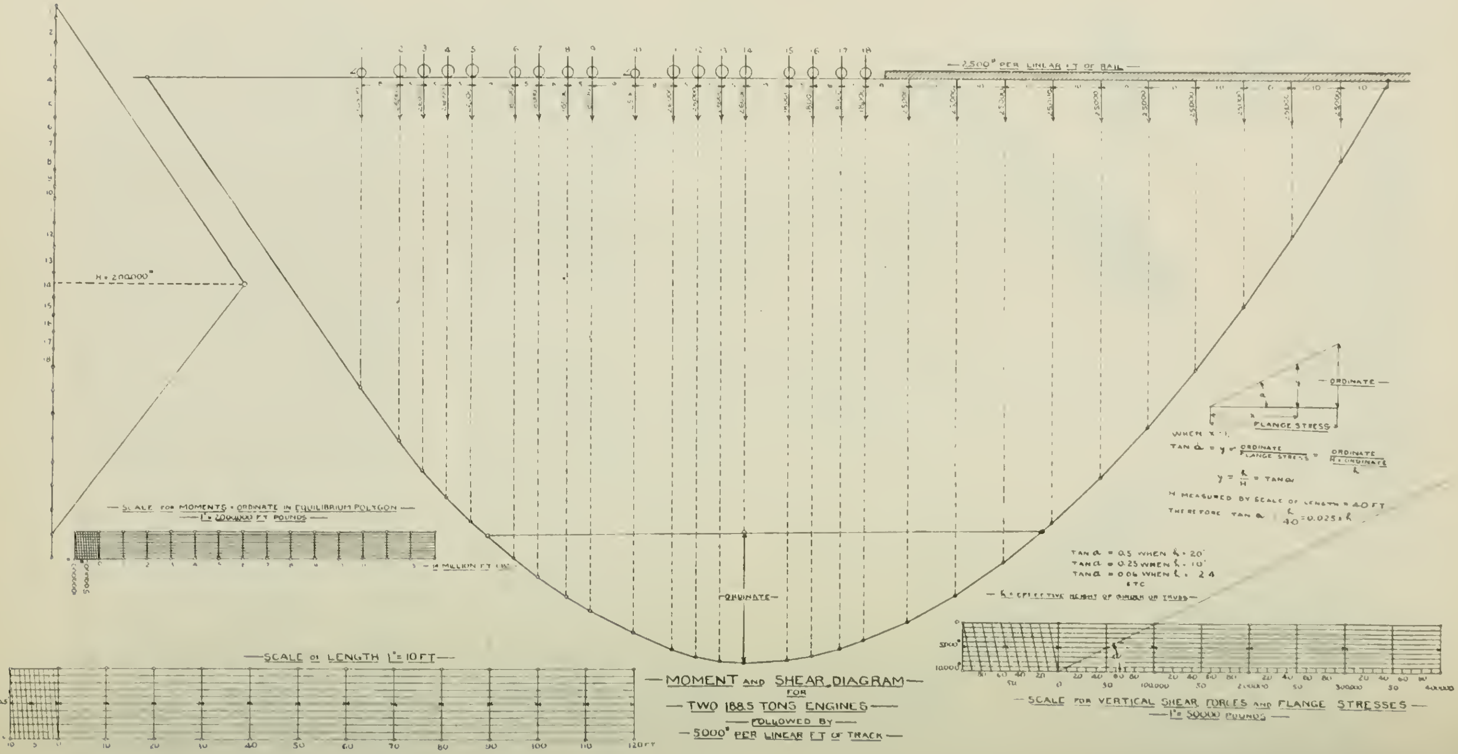
Read January 20, 1904

In presenting to the Society this little paper on "The Graphical Calculation of Flange Stresses in Girders and Trusses," I was led by the desire to bring some methods to your knowledge, which, as far as I know, have never been published anywhere.

Having recently had charge of the reinforcement of all the lines of the Manhattan Railway Company, of New York City, under the direction of Mr. Geo. H. Pegram, the chief engineer, I had to deal with such an enormous amount of figures for calculating the longitudinal and cross girders under many different loadings, that I made up my mind to reduce the tedious manner of obtaining stresses to a more systematic method. Having always been a great lover of the graphical calculation of stresses, I started to work out a method by which all girders of different length and depths, were figured with one diagram, for one kind of loading. The result was not only to reduce the tedious work of calculation, but to succeed in getting records of all important calculations by graphics, which showed in a clear manner all flange and web stresses. I am not in a position to show you the full extent of my work, but from the following picture you may conclude that the rest of the work was done just as systematically as this.

This diagram shows the effect of the longitudinal girders on the cross girders; it is simply the application of well known graphical principles. This loading, of course, is such that it will give the maximum reaction when one of the heavier wheel loads will be over the floor beam. On the elevated road in New York, where spans vary from 26 to 70 feet, and where, in many instances, the adjacent spans vary also considerably, this method proved to be a very satisfactory and quick one. On a railroad viaduct where the spans, for instance, are mostly all alike, this method is probably not of very much advantage. But to show you the process of getting the flange stresses in girders and trusses, I have here a diagram which was made for two 188.5 tons engines, followed by 5,000 pounds per lineal foot of track, to be used for the new standards of the Northern Pacific Railway. The main part of this diagram is well known to you all.

This diagram can be used with great accuracy for the calculation of spans, varying from 30 to 250 feet—of course always assuming the same loading; should, however, for some reason or another, any uniform load precede the wheel loads, this would be taken care of by a very simple construction of a parabola, using simply the last line of the equilibrium polygon next to the load No. 1 as the tangent. But this is nothing new; however, there is one feature in this diagram which may interest you, as it enables one to use the maximum



—2500# PER LINEAR FT OF RAIL—
H = 200,000#
—SCALE FOR MOMENTS = ORDINATE IN EQUILIBRIUM POLYGON—
—1" = 200,000 FT POUNDS—
= 14 MILLION FT LBS
—SCALE OF LENGTH 1" = 10 FT—
0
10
20
30
40
50
60
70
80
90
100
110
120 FT
—ORDINATE—
ORDINATE
FLANGE STRESS
WHEN x = 1,
TAN α = y = ORDINATE / FLANGE STRESS = ORDINATE / (H × ORDINATE / h)
y = h / H = TAN α
H MEASURED BY SCALE OF LENGTH = 40 FT
THEREFORE TAN α = h / 40 = 0.025 × h
TAN α = 0.5 WHEN h = 20'
TAN α = 0.25 WHEN h = 10'
TAN α = 0.06 WHEN h = 2.4
ETC
— h = EFFECTIVE HEIGHT OF GIRDER OR TRUSS —
5000#
10000#
100,000
200,000
300,000
400,000
—SCALE FOR VERTICAL SHEAR FORCES AND FLANGE STRESSES—
—1" = 50000 POUNDS—

—MOMENT AND SHEAR DIAGRAM—

FOR

—TWO 188.5 TONS ENGINES—

—FOLLOWED BY—

—5000# PER LINEAR FT OF TRACK—

moment ordinate directly, to determine the flange stresses of any girder or truss, and of any span or depth.

As shown in the diagram, we can obtain by a very simple mathematical deduction an equation which gives a value of the angle *a*, expressed as a function of the depth of h of the girder or truss to be calculated and the pole distance H; this value being tangent $a = \frac{h}{H}$; the values of h and H measured in the scale of lengths. This equation gives a straight line, of which any ordinate will give in the abscissa, the value of the flange stresses.

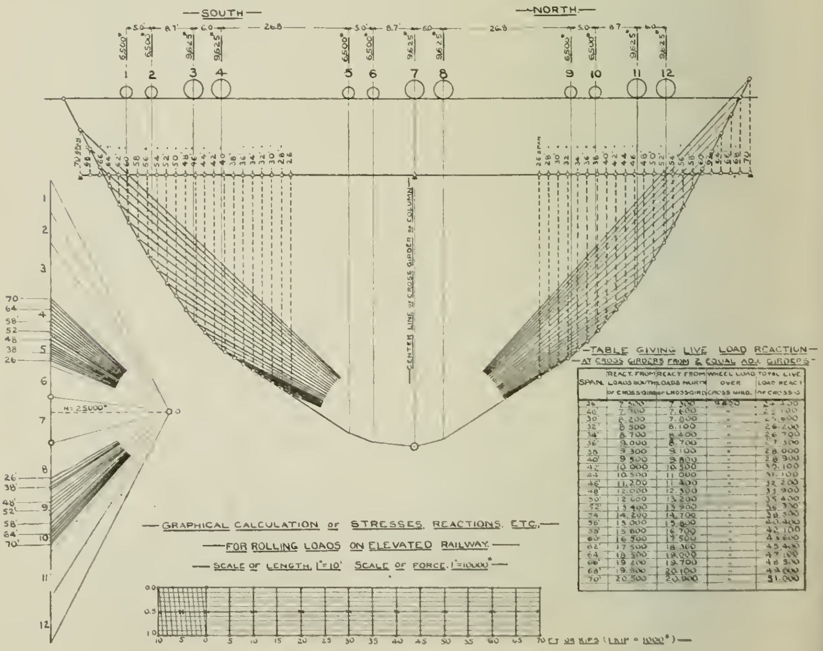
The operation of thus calculating flange stresses is as follows:

1st. Plot carefully the polygons of forces and equilibrium to any convenient scale, according to well known principles of graphic statics.

2d. Prepare on tracing cloth an outline diagram of the girder or truss to the same scale as that of the lengths in the polygon of equilibrium; draw perpendicular lines through sections of girder or truss where it is desired to determine the maximum moments.

3d. Find the position of wheels which will give the maximum moment. This can best be done by trial.

4th. Where vertical lines at the two extreme ends of girders or trusses intersect the equilibrium polygon, draw through these points the closing line, and the ordinate under the section in question will determine the flange stress.



—GRAPHICAL CALCULATION OF STRESSES, REACTIONS, ETC.—
—FOR ROLLING LOADS ON ELEVATED RAILWAY.—
—SCALE OF LENGTH, 1"=10' SCALE OF FORCE, 1"=10000#—

—TABLE GIVING LIVE LOAD REACTION—
—AT CROSS GIRDERS FROM 2 EQUAL ADJ. GIRDERS—

SPAN.	REACT. FROM LOADS SOUTH OF CROSS GIRD.	REACT. FROM LOADS NORTH OF CROSS GIRD.	WHEEL LOAD OVER CROSS GIRD.	TOTAL LIVE LOAD REACT. OF CROSS G.
26'	7,300	7,100	9,600	24,000
28'	7,900	7,600	"	25,100
30'	8,200	7,800	"	25,600
32'	8,500	8,100	"	26,200
34'	8,700	8,400	"	26,700
36'	9,000	8,700	"	27,300
38'	9,300	9,100	"	28,000
40'	9,500	9,800	"	28,900
42'	10,000	10,500	"	30,100
44'	10,500	11,000	"	31,100
46'	11,200	11,400	"	32,200
48'	12,000	12,300	"	33,900
50'	12,600	13,200	"	35,400
52'	13,400	13,900	"	36,900
54'	14,200	14,700	"	38,500
56'	15,000	15,800	"	40,400
58'	15,800	16,700	"	42,100
60'	16,500	17,500	"	43,600
62'	17,500	18,300	"	45,400
64'	18,500	19,000	"	47,100
66'	19,200	19,700	"	48,500
68'	19,900	20,100	"	49,600
70'	20,500	20,900	"	51,000

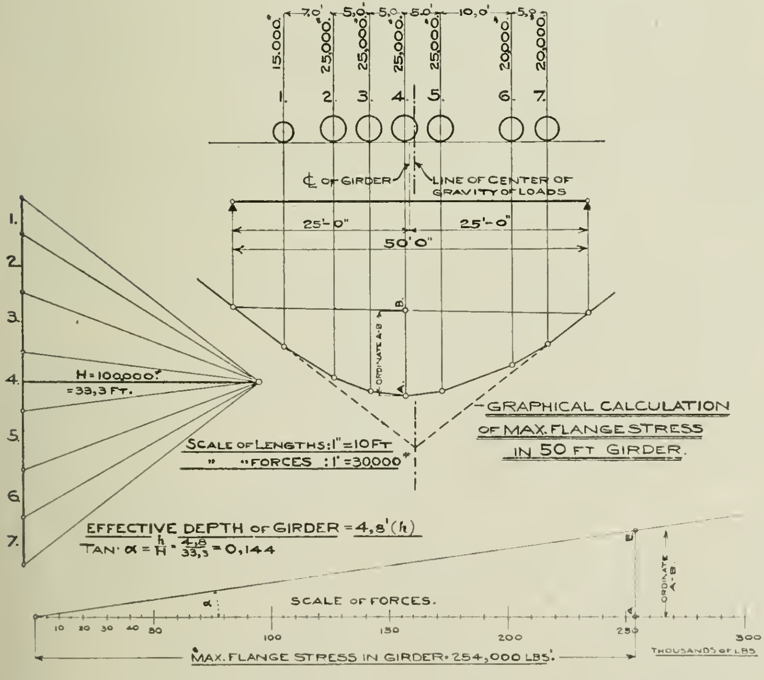
5th. Lay out the scale used for the forces, making it a diagonal scale to get closer results.

6th. Construct the angle *a* as function of *h*, the effective depth of girder, and *H* the pole distance.

7th. Take the ordinate as found in (4) in the dividers; where this vertical distance will strike the two sides of the angle *a*, read off on the horizontal side the amount of flange stress.

I may add that by this method, time and tedious calculations are saved. By a careful plotting of this diagram the results of these graphical calculations are correct within 1 per cent, which is, of course, sufficient for all practical purposes. After these diagrams are prepared, a man, with a little practice, could figure out about 5 strain sheets a day.

To illustrate the application of the above method of the graphical calculation of maximum flange stresses, below is shown an example for a 50-foot girder. The wheel loads are so placed as to give the maximum flange stresses. The whole operation is shown explicitly and needs no further explanation. The diagramatic work was checked analytically, and showed a satisfactory correctness of the results by this graphical method.



GRAPHICAL CALCULATION OF MAX. FLANGE STRESS IN 50 FT GIRDER.

BY ANALYTICAL CALCULATION FLANGE STRESS FOUND TO BE 252,600 LBS.

THE PRESERVATION OF WOOD FROM FIRE AND DECAY.

Joseph L. Ferrell, of Philadelphia

Presented January 20, 1904.

If wood and fabrics of all kinds were by their original nature uninflammable or incombustible, no fire problem would arise. Eliminate from wood and fabrics, absolutely or relatively, all tendency to inflame from fire generated in other inflammable substances, such as paints, varnishes, etc., and the fire risks fall away to infinitesimal proportions. Added to the natural combustibility of woods and fabrics is the increased combustibility of those materials from the oils and varnishes employed to create ornamental effect. If the use of inflammable paint, oils and varnishes can be curtailed in interiors, a great diminution of flammable conditions will be accomplished.

For the system developed by the writer, the following practical results are claimed:

1st. The elimination of the property of inflammability from wood and other fibrous substances, by impregnation with a permanent non-combustible chemical.

2d. The practical plating of wood surfaces with an enamel, all of whose constituents are absolutely insoluble and infusible.

3d. The permanent protection from decay of all wood by impregnation with a chemical solution.

It is not intimated that wood will endure infinitely an increasing attack of flame without charring or disintegrating; but it is asserted that when wood which has been treated is attacked by long continued flame, it will not receive, or increase, or transmit flame. In that case all flame existing will be only that of the extraneous substance, and the attacked wood will add nothing to it; and, moreover, the wood attacked will disintegrate with exceeding slowness compared to what it would if untreated.

A test was made in the grounds of the New York Shipbuilding Company, at Camden, N. J., to ascertain the value of this treated wood. Two wooden houses were built. One of them was of treated wood, the other of natural wood. Both were alike in every respect. The officials of the company conducted the test. Under each house was placed a mass of yellow pine sicks, and on all four sides were piled several cartloads of Georgia pine. In 16 minutes after fire had been applied the untreated house was utterly consumed, while the treated house was but slightly charred. The door of the latter was then opened, and it was filled 5 feet high inside with shavings and fat pine logs. Over all was distributed 10 gallons of coal oil. The mass was fired. At the end of 23 minutes the door (which was not even burned through its panels) was opened. And although all the fire wood was burned up, not a particle of flame adhered to the wood of the building. It was taken apart and held ready to be put up for another test.

The chemical agent employed is sulphate of alumina, which costs but about 75 cents per 100 pounds. This is an antiseptic and preservative material which remains permanently in the wood. The strength of the solution is about 15 degrees Beaume. In treating ties and bridge timbers, which are to be made proof against decay as well as against fire, an addition is made of some ferric sulphate to the alumina solution, this latter material acting as a coagulant. The solution, in either case, is applied under a pressure of 450 to 600 pounds per square inch, the pressure being varied according to the character of the wood under treatment. No preliminary steaming or vacuum process is employed. When flame or intense heat is applied to the treated wood, the wood will char at the point of contact, but will not burst into flame, and the destructive effect of the heat will be confined to the point of contact with the flame. When untreated wood is coated with a paint of which the sulphate of alumina forms the basis, the application of heat causes the paint to form a rough, hard crust, which protects the wood beneath.

In impregnating wood to render it fireproof, cylinders of moderate size are used, each holding a single railway tie, a timber of commercial size, or a bundle of planks, etc. The cylinders are of cast steel, and tested to 1,000 pounds pressure. At each end is a gate, internally sealed, and moved vertically by hydraulic power. In 1-inch planks the treatment lasts about half an hour; larger sections in 10-foot lengths require longer time. The time varies from 15 minutes to two hours, according to the character and size of timber, etc.

Wood, textile fabrics, theatre scenery, etc., can be simply and effectively treated so as to eliminate all possibility of their receiving or extending flame. The fundamental proposition is to remove the possibility of flame, or, at least, reduce its volume to the minimum. When this is done, it is no longer necessary to consider wood or textile fabrics as matter for the mass of flame to be encountered. After that, the chief consideration will be to cover the case of the smaller aggregate of other things, which may produce the attacking flame.

Thus far, consideration has only been given to the case of wood impregnated with sulphate of alumina, which can only be effected in a proper plant. It cannot therefore have any bearing upon the protection of existing buildings, except as providing flooring so treated to be laid down upon existing old untreated flooring, or, as treated trimmings of interiors to replace old untreated trimmings. But we expect to solve the problem of interior wood treatment by means of insoluble and infusible enamel coatings of any shade of color.

A surface coating on wood must respond to many imperative and most difficult conditions. No element of its volume can be either inflammable, volatile, soluble, or fusible. It must be powerfully adhesive, and must be a rapid dryer. It must have cohesive properties of the strongest character. It must dry into a flint-like mass, and exhibit a smooth surface. It must be susceptible of taking up into itself all shades of ornamental color. It must not, like paint, curl up and scale off on fire application, but must maintain very uniformly, over the attacked surface, a solid body. This set of conditions is very difficult to meet.

The same material may be used in a solution to be applied to draperies and scenery. It is not to be understood that this will render them absolutely immune to flame, but that it will nullify the inflammability which naturally exists in them. If flame attacks them they will not burst into flame, or extend the flame, or even increase the original volume of the attacking flame.

DISCUSSION.

Gen. William Sooy Smith—Does treating the wood in this manner affect its strength in any manner?

Mr. Ferrell—Not in the least.

Gen. Sooy Smith—What is the capacity of each tie treating machine?

Mr. Ferrell—With the 40 machines we can treat 3,000 ties a day, and we treat each tie singly.

Gen. Sooy Smith—How much does the saturation increase the weight of the wood?

Mr. Ferrell—About 9 per cent, after thorough drying. Of course the hard woods are not as susceptible to saturation as the soft woods, and do not receive the same percentage of the saturation. The highest average of the normal percentage of saturation of oak would be about 65 per cent, and some not over 45 to 50 per cent. Maple will take about 95 per cent.

Mr. B. B. Carter—How about the cutting and sawing of treated wood; does it work as well?

Mr. Ferrell—Yes, I think you will find that it will cut about as easily as the untreated wood.

A Member—Does that treated wood resist the attacks of white ants?

Mr. Ferrell—About 2½ years ago I sent 500 feet of treated wood to a captain in the English army in Africa, and also sent some to another English gentleman in India. They put the wood in the ant hills themselves and left them buried there for two or three months, and they came out without being touched.

A Member—What wood did you use?

Mr. Ferrell—Yellow pine, white pine, and I think there were a few pieces of oak. As a result of that, Captain Kenneth Campbell and Sir Ralph Moore, of the English government in India, heard of it, and when they came home they got into communication with some gentlemen in London, made recommendations to the English government, and took up all my foreign patents.

Mr. Finley—We are a commercial people and I would like to ask what this treatment costs?

Mr. Ferrell—The average cost is about $9.00 per thousand feet. That is the net cost, including labor and everything else.

Mr. Finley—Can your enamel for fire resistance be applied on any surface, or must the surface be clean and smooth?

Mr. Ferrell—It can be applied to any kind of surface, and can also be put on top of paint.

Mr. Finley—Have you any time records, that is, can you give us instances of where this enamel has been in use for some time?

Mr. Ferrell—Yes, very complete records. The material is practically as enduring as glass. There is no possibility of its decay. This enamel, however, is for indoor use. There is another form for outdoor use. I have one material which, as a filler, is of such penetrating power that it will go through a ½-inch board, if floated and left over night, and that penetrating material is essentially a preservative, and fireproof as well. Of course it is a good thing for a preservative, but you would not, with all you might apply, get any more preservative power on the body of the wood than you would from the paint, but you would get quite as much as from any paint.

We are saturating wood wherever we can for new buildings, and repairing other buildings with saturated wood; but we are not attempting to do the impossible. Where we are coating the wood for protection against fire we are doing the best we can to get the initial material in as far as it will go, to preserve the wood; but in very few cases would that go from front to back in vertical wood. But indoors, where you have no conditions of a strenuous character, the decay is very slow, even under natural conditions.

Mr. Finley—I understand you are also preserving railroad ties. What records have you of time, where ties have been in the ground?

Mr. Ferrell—We have none whatever. We ought to have several, but we have practically none. All things seem to have a beginning.

Mr. Finley—What can you say of it as a preservative, as compared with processes now used, such as creosoting?

Mr. Ferrell—When you coagulate the albuminoids you perform two functions—you take away the food of the germs, and by the very act of coagulation, the whole of the chemical injected is made very hard. Take fine sulphate of alumina, which always tends to stay where it is; it hardens the material in every sense, and thus makes it absolutely impossible to get out, and without any additional mechanical function you succeed in keeping the material more thoroughly in than it otherwise would.

Mr. Finley—Would that enamel be a preservative against fire in the wooden smoke-jacks used in railroad round-houses for the locomotives?

Mr. Ferrell—Undoubtedly; it will endure the flame of a Bunsen burner for five or seven hours.

Mr. Finley—I think most of us are a little skeptical on these matters, until we have very thorough proof of their value. I have seen a great many experiments on flame-proof paint, which, at the time of the experiments, seemed to be very satisfactory, but which afterwards did not come up to the experiments.

Mr. Ferrell—I expect to encounter that feeling, and have already done so, but am encountering much less of this feeling lately. I am very careful about my statements about what can be done. I had an examination made by a committee of the Franklin Institute running over a whole year. The fire resistance question was the principal one in view at that time. That was three years ago, and on the strength of what they found, the whole committee of 65 (never before known in the history of the Franklin Institute, I was informed) awarded me the Elliott-Cresson gold medal.

Mr. E. N. Layfield—I would like to ask how long this process has been on the market as a commercial factor; the impregnating process and also the enamel?

Mr. Ferrell—Our patent work on other things has kept us back for years. I had to take out 15 patents in 28 different countries, and some were exceedingly slow, and the patent solicitor forbade us to go ahead and do anything, practically, except to use the machine for fireproofing wood. For this reason, so far as the fireproofing of the wood is concerned, we have only been able to work for about four years.

Mr. Layfield—Has anything been done in the way of fireproofing bridge timber?

Mr. Ferrell—The best way to find out is to treat a bridge timber and put it in place, then build a fire under it and keep it up for ten hours.

Mr. Layfield—You spoke about fireproofing theater scenery. Are we to understand that this is done with the same process as is used in impregnating wood?

Mr. Ferrell—What I would recommend in theaters would be that all the floors be coated with a plastic material which is absolutely impervious to fire; then make an additional flooring of not over ⅜-inch maple or oak, which has previously been saturated with sulphate of alumina. In this way a floor is simply and cheaply made fireproof beyond possibility to burn under any circumstances. In regard to fireproofing the scenery—the present treatment of a thin fabric to prepare it for water color painting—to make a size, in other words, upon which to use color—is done with a preparation of glue and whiting. Now, glue is exceedingly combustible, so that it is necessary to have some other substance to size the material, and that is found in the substance I have shown you in connection with the piece of canvas.

Mr. Layfield—Would that interfere in any way with its flexibility?

Mr. Ferrell—I rather doubt that it would be any less flexible than with the material now used for sizing. I think a very thin solution is all that would be necessary.

Mr. Jesse Lowe—I would like to ask if wood saturated in this way will resist the attacks of the teredo?

Mr. Ferrell—This material, followed by a subsequent saturation of chloride of calcium, forms a chemical double decomposition, the resultant principally being silicate of calcium. This is infusible and insoluble. It hardens and resists water action, and will largely resist any effort of the teredo to bore through the coating so produced.

SOME PERFORMANCE OF BOILERS AND CHAIN GRATE STOKERS WITH SUGGESTIONS FOR IMPROVEMENT.

A. Bement, M. W. S. E.

Presented February 17, 1904.

In this paper a steam generating apparatus is recognized as being composed of three principal features: Boiler, furnace and fire grate. The fact that some apparatus have no furnace but are composed of simply boiler and grate, is also recognized.

As the chain grate stoker is the only type of fire grate to be discussed, its functions may be defined as automatic feeding of the coal to the fire, and similar discharge of the ash; also supply of air for the combustion process. With the furnace its function is the correction of the necessarily imperfect action of the grate. That of the boiler is the absorption of the heat supplied to it.

The duty of the combined fire grate and furnace, or of the fire grate alone, is to assist in the production of heat and temperature, a distinction between which is recognized. The duty of the boiler consists in the transfer of this heat from the gases to water contained therein.

The automatic feature of the apparatus to be discussed is realized in larger measure than with any other type, for this reason the personal equation of the fireman is reduced to a minimum, and it lies largely in the power of the operating engineer to secure good efficiency (provided the apparatus is of good character) because the manipulation consists very largely in fixed adjustments of the automatic stoker machine. The subject of the boiler will be taken first. For this purpose the performance of a Babcock & Wilcox, two Heine and one improved Heine boiler is given. Their general dimensions are shown in Table A. Fig. 1, is a vertical longitudinal section which serves to show the improved boiler as well as that of the Heine design—the improvement consisting in the insertion of two horizontal baffles, which cause the hot gases to travel the length of the boiler three times among the tubes in place of one diagonal pass of the Heine design. In the illustration the path of the gases is shown by dotted arrows, and the two inserted gas baffles are indicated by the heavy horizontal dotted lines. The heavy arrow shows the travel of the gases through the tube surface of the ordinary Heine boiler. It will be seen that at the rear end of the lower inserted baffle of the improved boiler there is a considerable space provided for exit of dust. It has been found that a portion of the gas takes this passage and in so doing reduces its travel, so the full effect of the three passes was not entirely realized. In the application of this improvement to these boilers this opening was somewhat reduced.

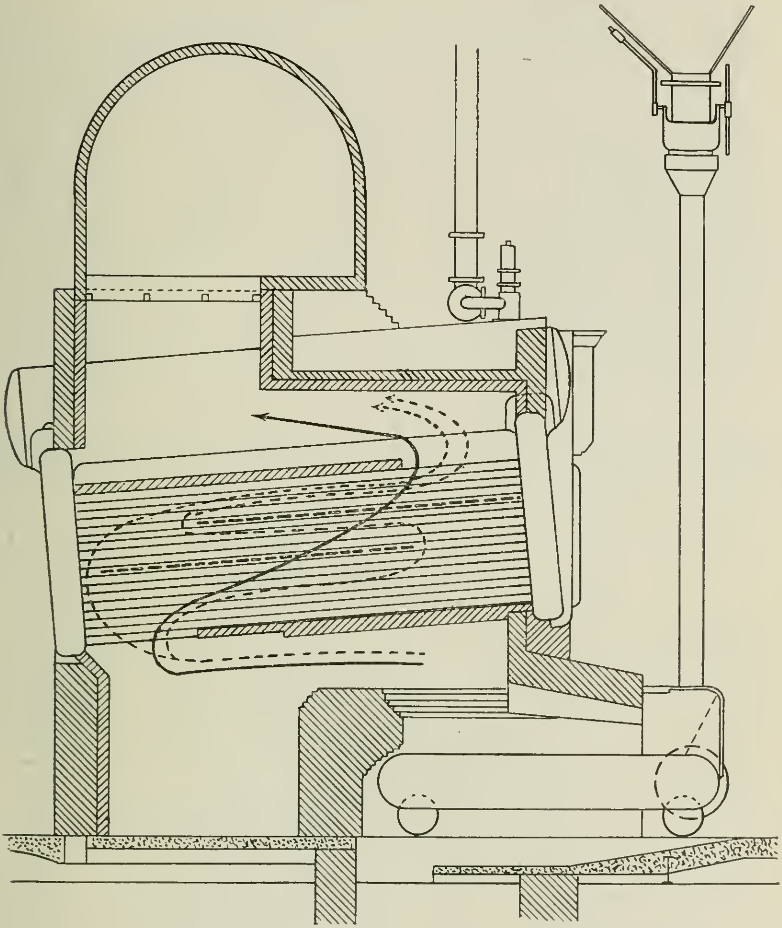


Fig. 1. Vertical Longitudinal Section of Nos. 1 and 2 and Improved Heine Boilers with Tile Roof Furnace.

Fig. 2 is a vertical longitudinal section of an example of the latest type of the Babcock & Wilcox boiler, having 5,000 square feet of heating surface, with large superheater. The boiler of this type to be discussed is a smaller example, but this illustration serves to show its relative features.

The expression "boiler efficiency" is used to designate the performance of the boiler only, not that of the combined apparatus; it implies the measure of the cooling effect produced on the hot gases, and neglects radiation and moisture in the steam. Two sets of experiments were made; the object of the first was to determine the relative efficiency of Heine boiler No. 1, and that of the Babcock & Wilcox. It will be observed that their size is nearly equal, being slightly more favorable for the Heine. The columns of group No. 1 in Table A, show the relations, while similar columns in Table B give the essential features of the relative performance of each of

TABLE A—DIMENSIONS OF BOILERS.

	TYPE OF BOILER			
	Group No. 1		Group No. 2	
	B. & W.	Heine No. 1	Heine No. 2	Improved Heine
Number of tubes high	12	15	17	17
Number of tubes wide	16	19	19	19
Length of tubes, feet	18	15.8	15.8	15.8
Diameter of tubes, inches	4	3.5	3.5	3.5
Square feet of water heating surface	4000	4340	4800	4800
Square feet of steam heating surface	383	....	....	....
Horse power, standard rating	400	434	480	480
Horse power, makers' rating	400	570	645	645
Travel of gases in contact with tube heating surface, feet	21	13	13.3	36
B. & W. chain grate stoker, square feet	65.5	72.2	72.2	72.2

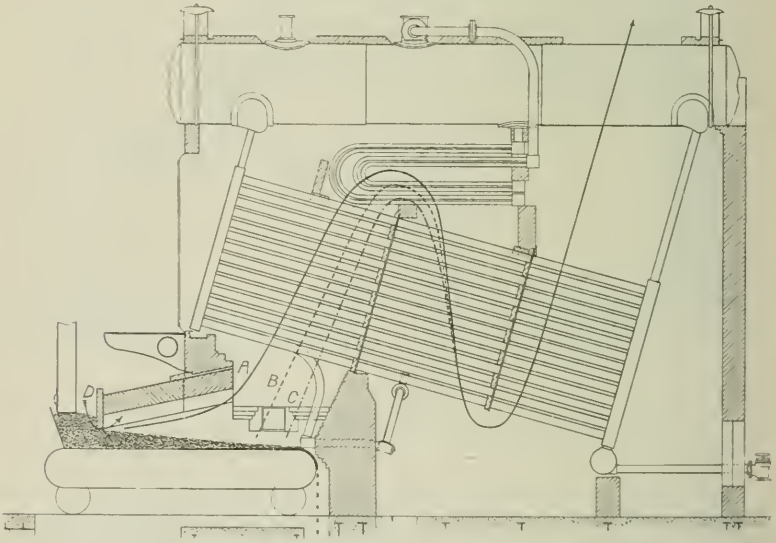


Fig. 2. Babcock & Wilcox Boiler, and Chain Grate Stoker.

the groups. With the boilers of the second group, it is observed that they are identical in size and design, with the one exception of the length of travel of the gases in contact with heating surface.

TABLE B.—PERFORMANCE OF BOILERS.

	TYPE OF BOILER			
	Group No. 1		Group No. 2	
	B. & W.	Heine No. 1	Heine No. 2	Improved Heine
Horse power developed	442.8	431.5	564.3	580.4
Horse power developed above standard rating	10.7%	....	17.6%	20.9%
Horse power developed below standard rating	....	.06%	....	....
Horse power developed below maker's rating	......	32.1%	14.3%	11.2%
Temperature of escaping gases, F. degrees	480.2	650.5	657	469
Temperature of escaping gases above saturated steam	127 8	273.1	278	92
Temperature of escaping gases above air supply	407.9	580.2	582	394
Temperature of saturated steam	352.4	377 4	379	377
Temperature of superheated steam	455.8	....	....	....
CO_2	9.22	7.93	10.7	10 3

The object was in one case to compare a Babcock & Wilcox with a Heine boiler, and in the other to determine the extent of the improvement made in the Heine boiler.

The tests between the Babcock & Wilcox and Heine No. 1 preceded those between the improved and unimproved Heine boilers, and it was the result of the first tests that led to the development of the improvement, which was devised by Mr. W. L. Abbott and the author for the purpose of increasing the efficiency of the boilers of a plant in which they are located, shown in Fig. 15.

The tests between the Babcock & Wilcox and Heine apparatus were made not only for the purpose of determining the boiler efficiency, but also that of the furnaces, while the object of the tests between the improved and Heine No. 2 was to ascertain relative boiler efficiency only. The results of the furnace performance will follow the discussion of the boilers.

The efficiency of a boiler* will be influenced by the initial or furnace temperature, and by the capacity at which it is worked. So as the horse-power increases, the effect is to lower the efficiency, and as the initial temperature is lower, so is the heat transfer. As a smaller boiler will absorb less heat than a large one, the determination of its efficiency, according to some standard, becomes a complicated problem. With the measure of performance of the combined boiler and furnace based on water evaporated from and at 212 degrees, a factor of evaporation has been devised to place different conditions on a common basis but no factor, or set of factors, has as yet been devised to reduce various boiler performances to any standard of comparison. Therefore to determine the difference in efficiency between the boilers to be compared, required that in each case the amount of heating surface, initial temperature and amount of water evaporated, be the same. These requirements being met, it then became possible to discover the relative value of the cooling effect produced. These requirements were met in the comparative test between the Babcock & Wilcox and Heine No. 1, and also between the improved and Heine No. 2. In fact, the performance of the four boilers is so nearly on the same basis as to be suitable for comparison. The results of the comparative trials are given in Table B, where in place of the initial temperature, its equivalent, the condition of combustion is used. With the Babcock & Wilcox it will be observed that the CO_2 is somewhat higher than with Heine No. 1. Owing, however, to a considerable loss by escaping hydrocarbons, this apparent superiority in furnace action was not realized. With the improved and Heine No. 2, conditions favored the latter somewhat.

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*Journal Western Society of Engineers, Vol. VI, page 231.

Conditions of operation being the same, the difference of cooling effect is shown by the difference in final temperature which in these tests was measured above that of the air supply; the steam pressure maintained in the plant containing the Heine boilers is 175 pounds, but with that of a Babcock & Wilcox a lower pressure prevailed. Therefore in calculating the curves of efficiency and fuel

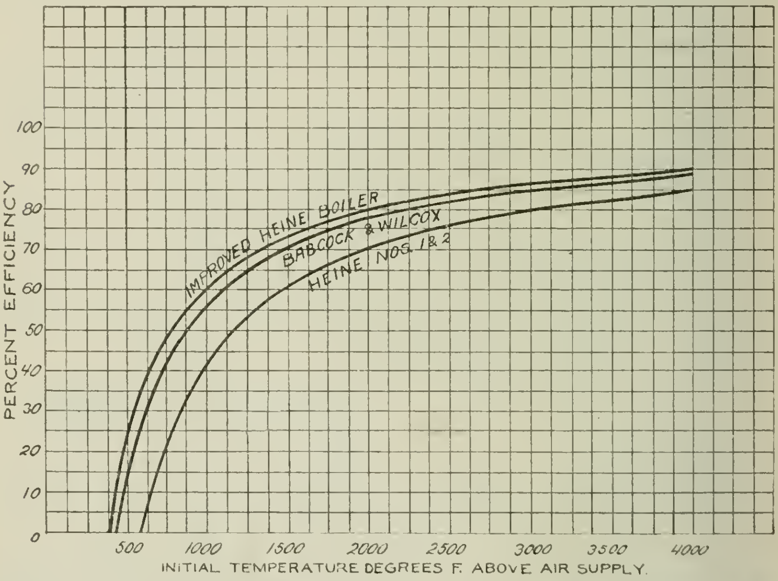

Fig. 3. Efficiency Curve of Heine, Nos. 1 and 2, Improved and Babcock & Wilcox Boilers.

saving for this boiler, the temperature of escaping gases is taken as greater by an amount equal to the difference between the saturated steam temperatures. This is because the temperature of the cooling medium has an effect on efficiency and for this reason the correction is employed. The relative efficiency of the boilers is shown by Fig. 3, the curves in which are calculated for all possible ranges of initial temperature, upon assumption that the final temperature remains constant over the full range of the initial. The respective final temperatures are shown in Table B.

The assumption that the final temperature is correct for any other condition except that of the tests in Table B, is not necessarily true, and to illustrate this feature experiments shown by A and B in Fig. 4 were made. Curve A was produced by letting the fire burn nearly out in the furnace of Heine boiler No. 2. This is not a working condition, but is one which necessarily causes not only a rapid drop in the initial temperature owing to increasing excess of air, but also in the final temperature owing to rapid decrease in amount of heat generated. Curve B is from measurements taken from different furnaces in regular active operation, and it is observed that the final temperature is very nearly constant. With a condition where the amount of heat generated remains constant and the initial temperature varies, owing to varying excess of air for example, the assumed curve C serves to illustrate the relation.

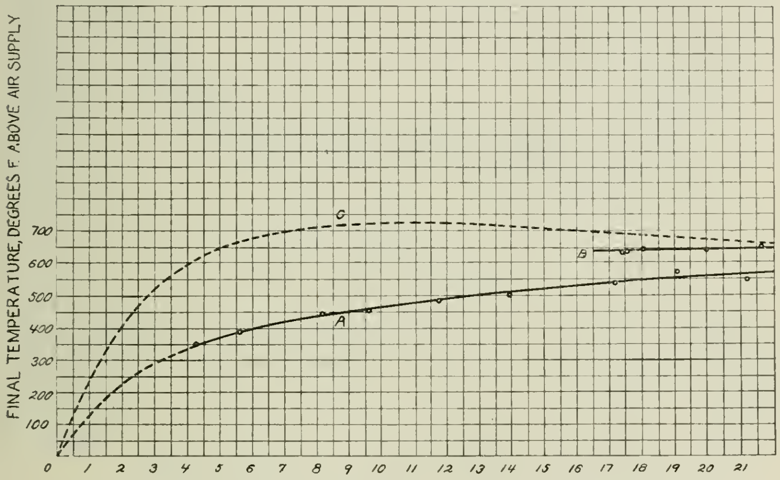

Fig. 4. Relation of Final to Initial Temperature with Heine Boiler.

The value of the relative efficiencies from the standpoint of fuel saving is quite important. It is shown in Fig. 5, the efficiency of Heine boilers Nos. 1 and 2 being taken as the standard. The value of an efficient boiler when served by an inefficient furnace, is forcibly illustrated. Tests between the improved and Heine boilers No. 2, showed fuel saving as high as 25 per cent for the former over the latter, and served to prove that the relative efficiency of the various boilers as given in Fig. 3 is approximately correct, for any working condition.

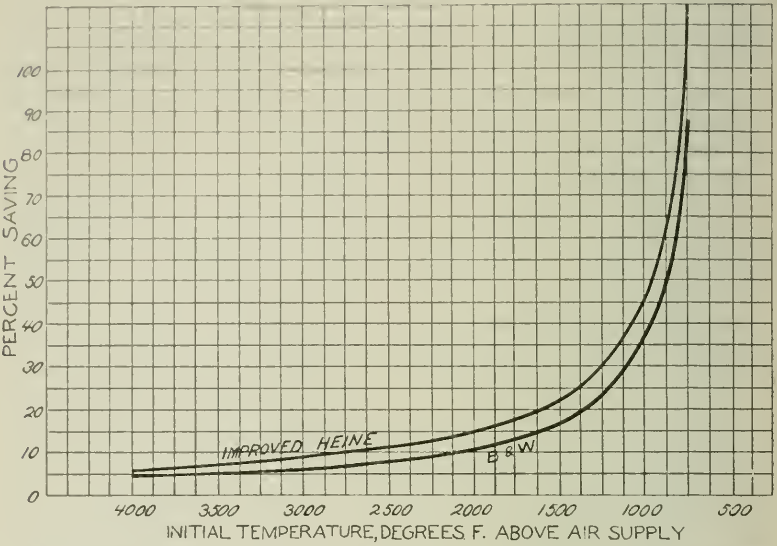

Fig. 5. Saving made by Babcock & Wilcox and Improved Boilers over Heine Nos. 1 and 2.

TABLE C.—DROP IN TEMPERATURE AND RESULTING WORK IN DIFFERENT PORTIONS OF B. & W. BOILER.

Temperature, initial	2012° F.	
'' at end of first pass	908° F.	
'' at top of second pass	680° F.	
'' at bottom of third pass	555° F.	
'' final	480.2° F.	
Drop in temperature first pass	1107° F.	72.064%
'' '' '' drums	158° F.	10.29%
'' '' '' superheater	70° F.	4.59%
'' '' '' second pass	125° F.	8.16%
'' '' '' third pass	75° F.	4.896%
Total	1532° F.	100.000%
Horse power developed in first pass	321	
'' '' '' '' drums	41	
'' ' '' '' second pass	35	
'' '' '' '' superheater	20	
'' '' '' '' third pass	22	
Total	442	

Inasmuch as there is a great difference in the cooling effect between the boilers compared, it will be interesting to study the reason therefor, and also to examine the drop in temperature of the gases on the way through the heating surface. Regarding this latter phase of the matter, Table C gives in detail the performance illustrated in Fig. 6, which is a curve of temperature drop through the surface of the Babcock & Wilcox boiler plotted from measurements taken during the trial. From this it appears that the same length of travel in the last pass gave only 6.7 per cent of the cooling effect of the first pass, illustrating the importance of the gases being in contact with the heating surface for as long a period as practicable, if large cooling effect is to be secured. It is for this reason that the Heine boiler performance differs from that of the improved boiler and the Babcock & Wilcox.

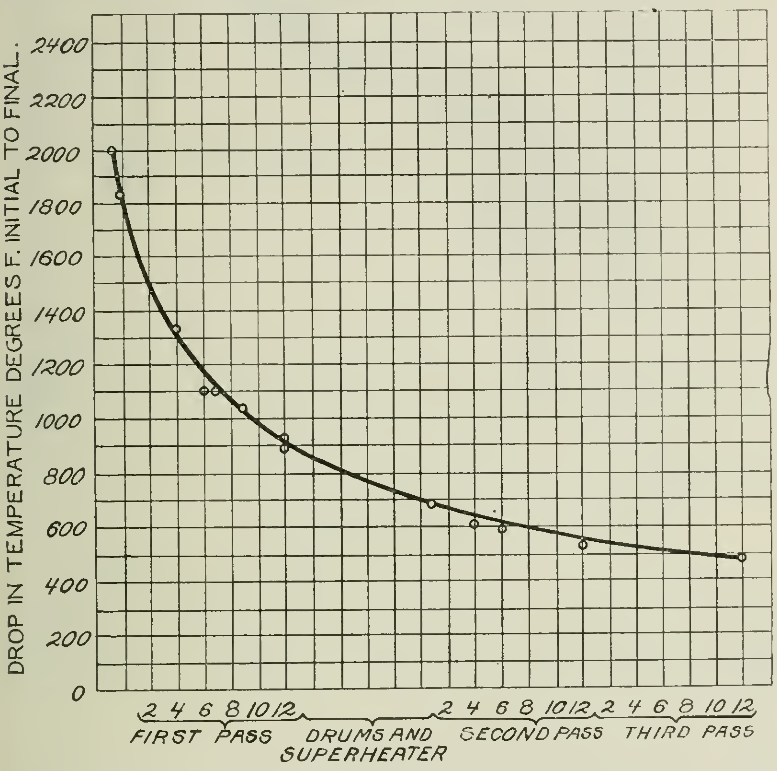

Fig. 6. Drop in Gas Temperature in Babcock & Wilcox Boilers of 400 H. P.

Various measurements were made among the tubes of the Heine boiler No. 2, which of course refer in relative measure to No. 1. These are shown in Figs. 7 to 11. Fig. 7 is a sketch of the tube surface of the boiler, with the tubes cut away; it serves to illustrate the path of the hot gases, and to identify the location of the measurements which are given in Figs. 8 to 11.

Fig. 8 shows the prevailing temperature among the tubes 45 inches back from the water leg, from the bottom to the top of the boiler on line Y of Fig. 7. The measurement at the first or lowest stay-bolt, shows the effect of the heat from the tile roof immediately over the fire. The minimum temperature is between the second and third stay-bolts; above this it rises until at the point of escape the maximum is reached, showing that on the line of the measurements the highest temperature is at the point of exit. The drop of the ninth measurement is owing to the sudden change in the path of gas travel over the end of the baffle at the top of the boiler, which causes the hottest point to be carried back slightly more than 45 inches at this ninth stay-bolt.

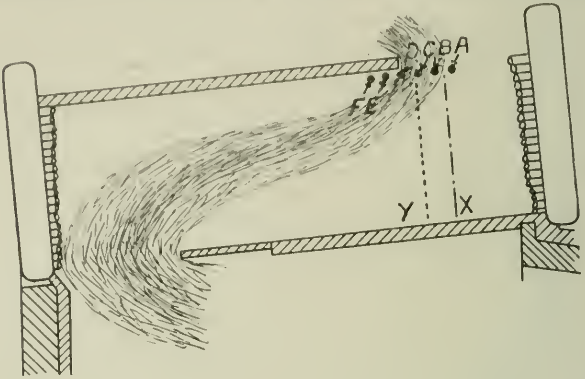

Fig. 7 Diagram showing path of gases through tube surface of Heine Boilers.

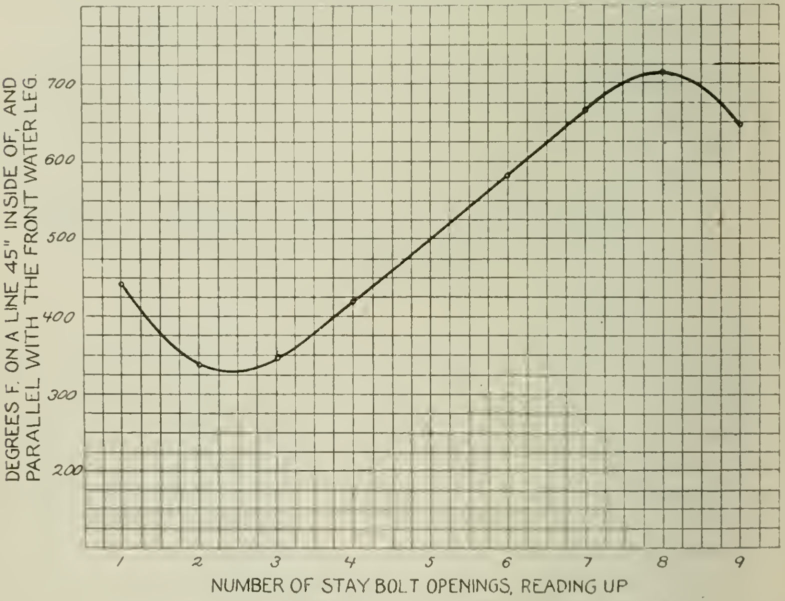

Fig. 8 Temperature Measurements, Heine Boiler No. 2.

Fig. 9 is a curve from measurements A to F, taken through the ninth or top stay-bolt on a horizontal line, as identified in Fig. 7 by corresponding letters, and which extended across and beyond the path of the gases at the exit from the tubes. The highest temperature is found at a point 46.5 inches from the inside face of the water leg. From this point in each direction there is a rapid drop as the distance increases.

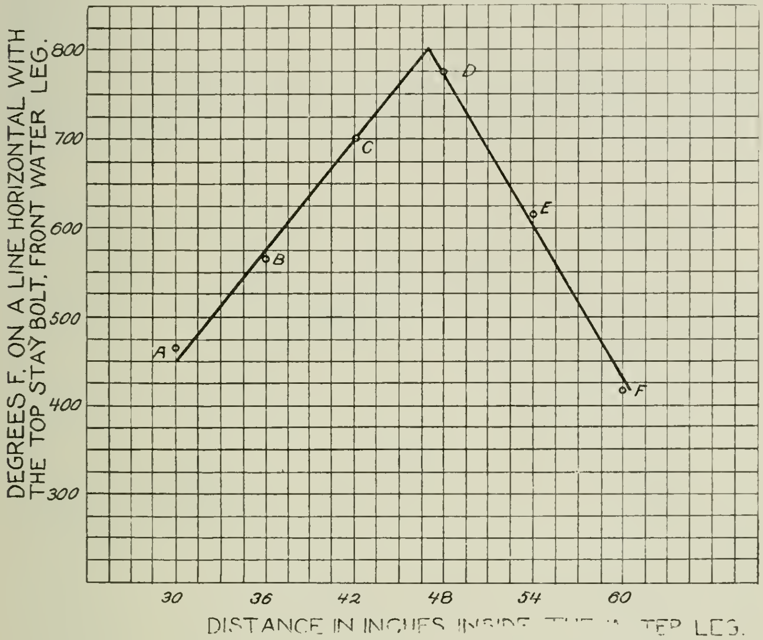

Fig. 9. Temperature Measurements from Heine Boiler No. 2.

In Fig. 10 one of the curves shows the percentage of carbon dioxide in the gases on line X, Fig. 7, 30 inches inside and parallel with the front water leg of boiler No. 2, and a corresponding curve from the improved boiler. It will be observed that the measurements in the lowest part of the front of boiler No. 2 are extremely low; the first two, however, show the effect of leakage through the furnace roof. The contrast between the boilers in this respect is remarkable. As analysis showed the CO_2 to be low on account of the presence of air, this air must have entered by leakage, and as such leakage could not be very large it follows that the path of the gases does not extend to the front lower corner of the boiler, or along close to the front water leg. This may also be considered proved by the curve of CO_2 from the improved boiler subject to the same leakage, but with an arrangement of baffles which cause the flow of the gases to be carried into the front lower corner and nearer to the front water leg. It is further illustrated by Fig. 11, giving CO_2 measurements across the path of the gases at the exit from boiler No. 2, showing that the CO_2 increases with the distance away from the water leg. From measurements made through the back water leg, it was shown that a similar condition to that in the lower front corner exists in the upper back corner of the tube surface, but on a reduced scale. With these boilers the back upper corner performs a small amount of work and the front lower corner still less; and the active portion of the heating surface is on a diagonal line from the lower back to the front upper corners. It shows further that the volume of the moving gas body is of decreasing magnitude as it proceeds, and that as its center is approached the temperature is higher, so it is probable that its center is moving at a much higher velocity than its surface.

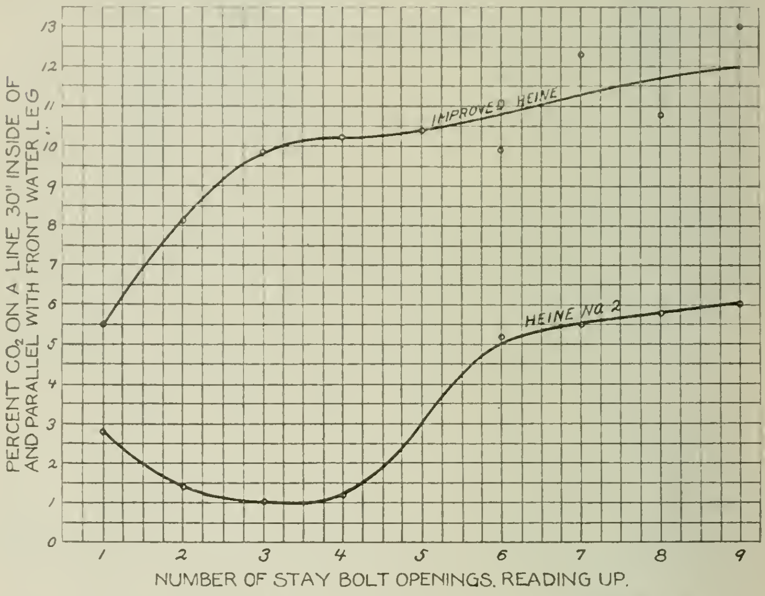

Fig. 10. Gas Analyses from Improved and Heine Boiler No. 2.

According to Fig. 7, it would appear that the greater portion of gas was flowing through the space of 1 foot at the front end of the top baffle, and if an opening 4 feet long from the furnace at the lower back corner is large enough, it would follow that a space considerably less at the outlet would answer. This fact has been recognized in the application of the improvement to the Heine boilers, as in all except the first experimental application, the opening at the end of the baffles has been proportioned to the volume of the gases. As the volume of the gases decreases rapidly with drop in temperature, it it probable that the Babcock & Wilcox boiler would be improved by passing them across it four times in passages of properly proportioned size, not adding to the amount of heating surface, but bringing more of it into use. This is because with this boiler, as with the Heine, or any other boiler, the tendency is for the gases to flow in a narrow path diagonally across the tube surface of the pass.

It is apparent that the greater efficiency of the Babcock & Wilcox boiler over the Heine No. 1 is not owing to difference in amount of heating surface, but to greater length of travel of the gases in contact with the same amount of surface; or, in other words, greater length of time for the `transfer of heat. This is still better illustrated by the improved and Heine No. 2.

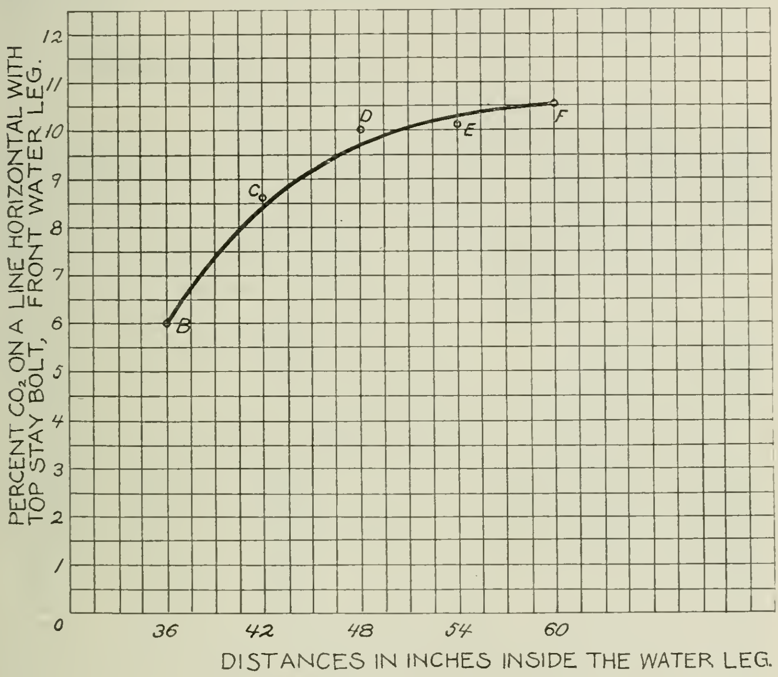

Fig. 11. Gas Analysis from Heine Boiler No. 2.

The superior efficiency of the Babcock & Wilcox as compared with the Heine is based on this particular one, which is a high "double-deck" apparatus, and it does not follow that a lower type would show such superiority. This may be illustrated by assuming that each boiler be reduced one-half in height, the effect would be that the length of the travel of the gases with the Babcock & Wilcox would be reduced 50 per cent, while with the Heine the reduction would amount to less than 5 per cent. As the height is less, the efficiency of the Babcock & Wilcox drops off very much faster, and while the gain in the high over the low Heine type is small, with the Babcock & Wilcox it is very large. This feature of the Heine boiler is illustrated by Fig. 12, a rectangle representing the dimensions of the tube space of the boilers. In the plant containing the Heine boilers under discussion, there are boilers of three sizes, the difference consisting in height only, as shown by Table D. That designated as No. 2 is one of the high boilers, and it was one of these that was improved by adding the gas baffles. Referring to Fig. 12, the relative location of the top of the tube surface of the low and medium boilers is shown by dotted lines, and the different length of line of gas travel is shown from 11 feet 5 inches for the small, to 11 feet 11 inches for the largest boiler. From this it appears that as far as capacity and efficiency are concerned, the smaller boiler is very nearly equal to the larger one. This fact is also proved by the tests of Nos. 1 and 2, as in the diagram of efficiency, Fig 3, these two boilers are represented by a single curve, not differing enough to allow the plotting of separate curves.

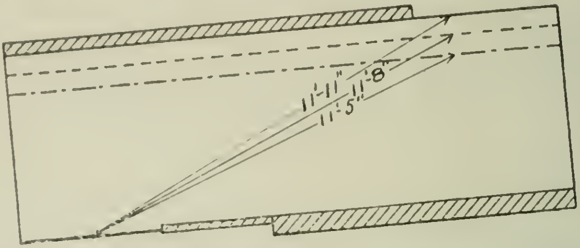

Fig. 12. Diagram showing length of Gas Travel in Heine Boilers of different heights.

TABLE D—RELATIVE RELATION OF HEINE BOILERS.

	High	Medium	Low
Length of tubes	15 ft. 8 in.	15 ft. 8 in.	15 ft 8 in.
Number of tubes high	17	15	13
Number of tubes wide	19	19	19
Vertical distance from bottom of lower tube to top of upper tube	63.0 in.	55.7 in.	49.5 in
Length of travel of gases in contact with heating surface, on straight line	11 ft. 11 in.	11 ft. 8 in.	11 ft. 5 in.
Square feet of heating surface	4800	4340	3800
Horse power, maker's rating	645	570	500
Horse power, standard rating	480	434	380
Actual relative value	1.04	1.02	1.00
Maker's assumed relative value	1.29	1.14	1.00
Actual horse power value on standard basis	395.2	387.6	380

The initial temperature, or in other words, the condition of combustion, has more effect on the efficiency of the steam generating apparatus than has the cooling effect of the boiler. This is shown by efficiency curves in Fig 3, and if choice lay between the two, that of high initial temperature would be chosen. But high initial temperature is dependent not only on an efficient furnace and grate, but also on skillful manipulation of the fire, while superior boiler efficiency has a fixed value not dependent on the skill of the operator, and this value increases as the initial temperature decreases. There might be some question as to whether the full value of a good furnace would always be realized, but there could be no failure to realize the value of an efficient boiler.

The most remarkable feature of this matter of boiler efficiency is that the simple addition of inexpensive baffles, with no labor cost for operation and requiring no additional room in the plant, gives results equal to an economizer requiring a large investment, considerable expense for maintenance, and a large amount of space for its installation.

THE STOKER AND FURNACE.

The chain grate receives its coal at the front at a uniform rate, and in like manner discharges the ash at the rear; in this respect it is an ideal machine. But the fuel bed is necessarily of unequal thickness, and for this reason, the distribution of the air supply cannot be in proportion to the requirements at all points; for example, the front end of the fire is a comparatively thick mass of freshly ignited coal, from which the volatile matter is rapidly being distilled, while the back of the fire is a thin bed of coke, through which an excessive quantity of air flows. For this reason it is impossible to secure a good condition of combustion at the fire, or in other words a desirable mixture of fuel and air. The result is that unburned gases flow away from the front of the fire, while an excessive amount of air passes through the fire on the back grate. Fig. 2 illustrates this condition, the arrow A represents hydrocarbon gases flowing away from the front, while B and C indicate the path of the unused air. It is observed that the combustible gases and air do not come in contact to sufficient extent to mix with each other, but flow in unmixed condition among the tubes of the boiler, with the result that by the time the mixture is attained, the gases have passed a sufficient distance among the tubes to cause such reduction of temperature as to make chemical action impossible, and in addition to a low efficiency, smoke results. The apparatus shown in Fig. 2 may be described as the combination of grate and boiler, lacking the furnace feature.

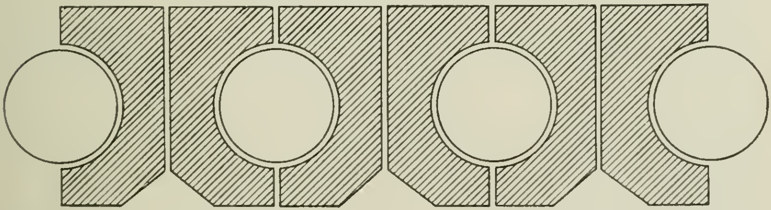

Fig. 13. Section of tiles encircling lower row of boiler tubes, tile roof furnace.

Reference to Fig. 1 will explain what the author defines as the furnace. It will be observed that the bottom row of tubes of the boiler are encased in fire brick tiles, shown in Fig. 13. The application of these tiles was devised by Mr. W. L. Abbott, and they extend beyond the bridge wall to within 3 feet of the opening to the tube surface. The intermediate space back of the encircling tiles is closed by the form shown in Fig. 14, which are those regularly supplied by the maker of the boiler, and leave the lower half of the tube exposed to the passing hot gas, and are usually known as the T tile. The distance from the coal gate at the front of the furnace to the end of this tile roof is 16 feet, a distance through which the gases must travel before coming in contact with the boiler surface except in the lower half of the bottom row of tubes. For a distance of about 3 feet back of the bridge-wall these are exposed, there being a distance of travel of 12 feet with no cooling effect, except that of radiation from the exterior furnace walls and through the tile roof. During the interval of time that the gases are moving through this distance of 16 feet their mixture is proceeding, so that before they have reached a point among the tubes where the temperature has dropped to a point below which union will be effected, the mixture is completed; or, as more generally understood, complete combustion is effected.

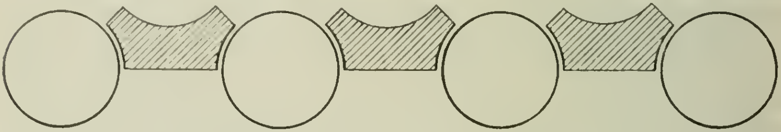

Fig. 14. Tiles closing spaces in lower row of boiler tubes back of encircling tiles.

The view, Fig. 15, shows the plant containing the Heine boilers above mentioned, and the tile-roof furnaces. The four tall chimneys serve 24 Heine boilers fitted with the tile-roof furnace; equipped with Babcock & Wilcox chain-grate stokers of a total grate area of 1,732 square feet, and having a total of 104,980 square feet of boiler-heating surface. The draught over the fire ranges from 0.15 to 0.45 inches of water. The shorter chimney on the right serves four Babcock & Wilcox boilers with a total heating surface of 20,000 square feet, equipped with chain-grate stokers having a total grate area of 306 square feet; the draught over the fire ranges from 0.20 to 0.25 inches of water. The character of the coal being burned at the time the photograph was taken is given in Table E, which is an average from laboratory records, and like all Illinois coal, it will make much smoke when conditions are favorable. The appearance of the four chimneys which serve the tile-roof furnaces, proves that their capacity to produce an effective mixture is ideal when uniformly supplied with fuel, which the chain-grate effectually does. It should be said that this photograph was taken when all the furnaces which discharge into these four chimneys were in service and working at maximum capacity, burning about 40 tons of coal per hour, and the chimneys discharging more than 1,000 tons of gases in a like period. The grates under the Babcock & Wilcox boilers were working at a corresponding rate, and the smoke from this chimney was not due to lower draft, because the strength of draught measured over the fires shows that a portion of the tile-roof furnaces have less than the Babcock & Wilcox boiler grates. There is of course a stronger draught in a tall chimney than in a

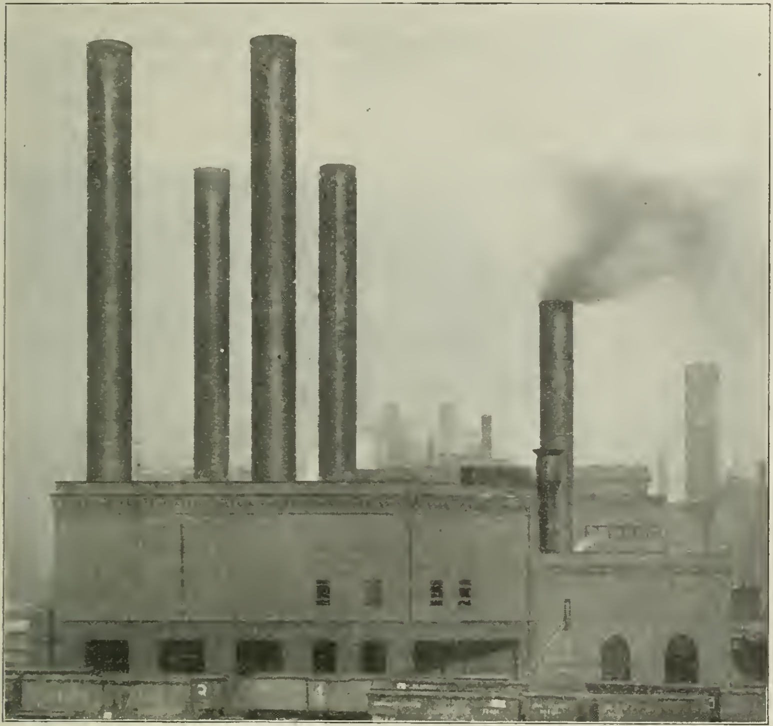

Fig. 15. Harrison Street Station - Chicago Edison Company.

TABLE E.—CHARACTER OF COAL.

Ash	15 per cent
Moisture	13.5 per cent
Heating Power	9652 B. T. U. per pound

Average Size.

Through screen of 0.25 inches	33.0 per cent
" " " 0.50 "	21.0 " "
" " " 0.75 "	15.5 " "
" " " 1.00 "	15.0 " "
" " " 1.25 "	11.5 " "
" " " 1.50 "	2.5 " "
Over " " 1.50 "	1.5 " "

short one, but this does not necessarily mean that draught at the fire is in proportion, because of different resistance of connecting flues. With each of these two kinds of apparatus the conditions of fuel, fire and air supply are the same; the only difference is that one is equipped with an effective furnace and the other is lacking in the furnace feature. In this connection * it is useful to present another case showing the effect of stokers discharging gases directly among the tubes of Babcock & Wilcox or similar boilers. Fig. 16 shows two chimneys on the left, each serving 3,5CO horse-power of these boilers which are equipped with plain grates fired by hand. The other smoking chimney serves a similar group of stoker-fired boilers.

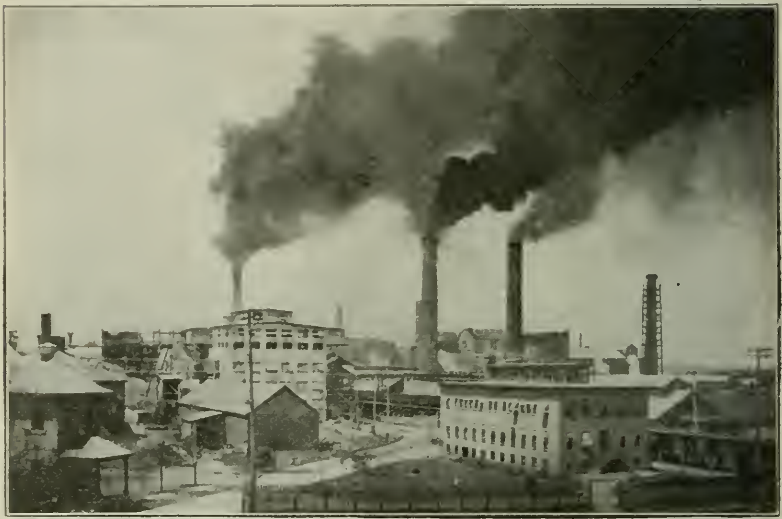

Fig. 16. Results from Hand and Stoker Fires under Babcock & Wilcox boilers.

The theory of the action of the tile-roof furnace may be given as follows: The coal entering at the front of the furnace has its volatile matter rapidly distilled in the form of a hydrocarbon gas, and flowing back meets a larger air supply from the back of the fire, where the fuel bed is thinner, and being thoroughly mixed in the chamber below the tile-roof it becomes, strictly speaking, a finished product of combustion which carries its heat from the furnace to the boiler. Assuming that the action of this furnace is as described, it would appear possible to obtain complete combustion with no air in excess. With one of these furnaces carefully worked and the air supply proportioned to the amount of coal being burned, by proper adjustment of the draught, it was possible to maintain an average of 17 per cent CO_2, and for a few short intervals as high as 19.3 per

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*Transactions of the American Society of Mechanical Engineers, Vol. XXIV, page 315 cent. Under such conditions, increase in the feed of coal would result in the apparent attainment of the theoretical maximum CO_2, after which any further increase in coal feed resulted in drop in CO_2, because coal being in excess, air was deficient, and some carbon oxidized to CO only. But no carbon was set free, therefore no smoke was produced.

Thus far, two of the features of the steam generating apparatus have been considered and a remarkably efficient example of each described, the tile-roof furnace appearing as an ideal device, and the improved Heine boiler as a remarkable example of an efficient apparatus. It is probable that this is the most efficient boiler of which there is any record. About the highest efficiency previously reported is that of a Thornycroft boiler, by Professor Kennedy, showing 86.8 per cent of the heat absorbed when evaporating 1.24 pounds of water per square foot of heating surface per hour, with a condition of combustion about the same as that with the improved Heine. Under these conditions the gases left at 41 degrees Fahrenheit above steam temperature. With, however, an evaporation of 3.2 pounds of water per square foot of heating surface and somewhat better combustion, the gases left at 165 degrees above steam temperature. In the case of the improved boiler the gases left at 92 degrees above steam temperature, when evaporating 4.17 pounds of water per square foot of heating surface per hour.

It is now in order to examine the chain-grate stoker, and discuss its characteristics from the standpoint of relative fuel and air supply. In this respect it is decidedly at fault, because the relative proportions of the machine are such that the air supply is greatly in excess of requirements, especially when such stokers are in combination with a furnace. This matter of air in excess is one that appears difficult for many to realize; the effect is to increase the amount of gas to be heated, but takes no part in heat production. The result is that the heat is expended in raising the temperature of a correspondingly larger amount of gas. For this reason its elevation of temperature is less because the fixed amount of heat must be distributed to a large amount of gas, and necessarily will not raise its temperature as high as when added to a smaller amount of gas. This is forcibly illustrated by observing the fact, that a certain quantity of heat may be present in a small amount of gas, at a temperature that will melt iron; or a like quantity of heat be present in a large amount of gas at a temperature that will freeze water, the heat being the same in each case, but the containing mass greatly different, which results in a corresponding difference in temperature. Thus is the distinction between heat and temperature illustrated. Heat only flows from a region of higher to one of lower temperature, and as the difference of temperature is greater, so is the rapidity or thoroughness of its transfer. This fact is of great importance with a boiler, because of the brief interval during which gases are in contact with it.

With a chain-grate stoker lacking the furnace feature, excessive air supply is effective in reducing incomplete combustion, but this phase of the matter has no application to the tile-roof furnace, and so will be discussed later.

The magnitude of the heat loss owing to excess of air, or in other words low initial temperature, is shown in Fig. 19, but an illustration presented directly in money loss may be useful. With coal of 10,000 B. T. U. per pound; at $1.50 per ton; final temperature of 670 degrees F. and air present equal to three times that actually required. The loss owing to this excess will cost $0.45 per ton of coal actually burned. A smokeless chimney is evidence of complete combustion but not necessarily of economical condition; and the cause of low efficiency is often ascribed to such minor losses as blowing of safety valves, coal used to bank fires, and fuel lost in the ash pit, ignoring the important loss due to air, as well as that of incomplete combustion.

The air leakage with chain-grate stokers is from three sources: First, at the back between the grate and bridge-wall; second, through the coal in the hopper and under the coal gate; third, through the fuel bed.

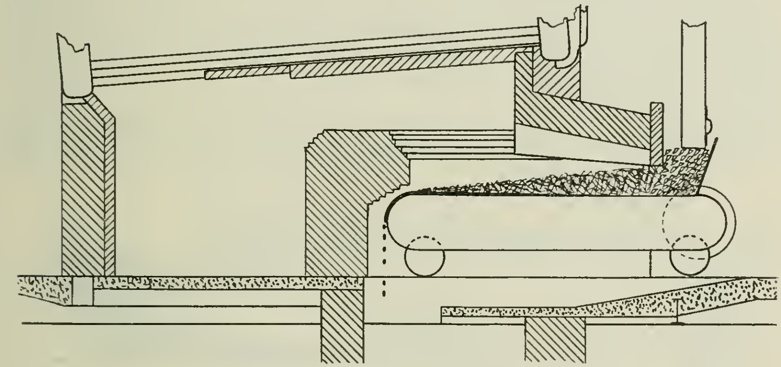
The remedy for the first consists in closing the openings at the sides of the stoker frames, between the bottom chain and the floor under the stoker, and between the upper and lower chains. This latter requires not only a damper extending from each chain, but that it have horizontal extensions sufficient to extend across, and make a close contact with two joints of the chain, because with a simple vertical damper air can pass its edge by way of the space between the thin portion of the chain links. In addition to this, a tight ash-pit is required. This method consists in preventing air reaching the opening at the back of the grate instead of closing the opening at this point. Various schemes have been employed to prevent leakage at the end of the grate, by building the bridge-wall extension so that it is close to the grate, and by using a water cooled metal box or pipe similarly located. These methods, however, are less effective than that first mentioned, and have some objectionable features.

The remedy for the second source of leakage consists in a greater depth of coal in the hopper. Arrow D, in Fig. 2, shows how such leakage occurs.

The third class of leakage, that through the fire can be corrected by maintaining a thicker fuel bed.

The lowest obtainable air supply in the tile-roof furnaces at full draft, with the chain grates as installed by the maker, ranged from 475 to 315 per cent, which was reduced by closing the air leaks about the chain, and by maintaining a greater depth of fuel in the hopper, to 250 to 200 per cent under best conditions. Such performance was obtained with coal shown in Table E, which may be considered as cheap fuel, which the stoker is intended to use.

Fig. 17 shows the tile-roof furnaces with the stoker machine as originally installed, but the coal hoppers have been made deeper, and the coal feed spouts shortened. As will be observed, the fire on the grate and coal in the hopper are shown at maximum thickness, which thickness is not sufficient to utilize the full air supply; for this reason it is proposed to raise the igniting arch, and to proportion the coal gate and hopper so that a condition as indicated in Fig. 18 may be realized. Here the coal hopper is so deep as to require an extension handle by which the spout may be moved, and as the temperature at the front of the furnace will be high, on account of the reduced air leakage through the coal in the hopper, provision must be made to prevent the coal catching fire before it reaches the bottom of the gate. To accomplish this, a closed air space on the front side of the gate is shown.



No. 17. Furnace and Stoker with thin fire.

With chain-grates as at present proportioned, the available thickness of fire is such that highest efficiencies are had with lowest draught, especially when it is induced by a chimney or fan. Increasing strength of draught is accompanied by drop in efficiency owing to increasing air supply, but capacity rises to a certain maximum, after which it begins to fall, owing to the rapidly diminishing initial temperature overcoming the advantage of increasing quantity of heat generated. If intensity of draught be carried far enough, capacity and efficiency will fall to zero, because the initial temperature owing to increased excess of air will become too low to ignite the coal. In other words, the fire will go out. This is proved by the fact that in ordinary every day experience with strong draught, when the coal is comparatively large in size it fails to ignite, and the operator learns by experience that the remedy lies in partially closing the damper.

One of the apparent faults of the chain-grate, is that it discharges a quantity of unburned coal with the ashes; the remedy for this is extremely simple, and consists in operating the stoker so that the fire is burned out before it reaches the end of the grate. But it is found with stokers as at present proportioned, that this results in such increase of excess of air as to offset the gain. Therefore, the thick fire is offered as a remedy for loss of cōke in the refuse. Why this result may be expected is explained as follows: Let it be assumed for example that a fire 17 inches thick at the front, and in the tile-roof furnace, with its end at the end of the grate, results in the fuel being in excess, or in other words air deficient. Such condition may be remedied by reducing the speed of the grate, so that the fire burns out before it reaches the end, the result is that more air flows in at the back which satisfies the combustible gas from the front of the fire, by mixing with it in the chamber of the furnace, resulting not only in full heat development, but attainment of maximum temperature.

According to the above, the usual form of overhanging bridge-wall would have no office to perform. This in fact is true. As however, there is danger that careless stoker operators will, owing to inattention, allow fire to go over the end of the grate, some form of bridge-wall could (if necessary) be employed. The best and least expensive scheme of this character is shown in Fig. 18, consisting of two metal pipes joined at the inner end by a return bend, water flowing in to one pipe and out of the other, above which the brick wall is built. Such a feature, however, should be unnecessary, because it is an expensive and inconvenient form of insurance against carelessness.

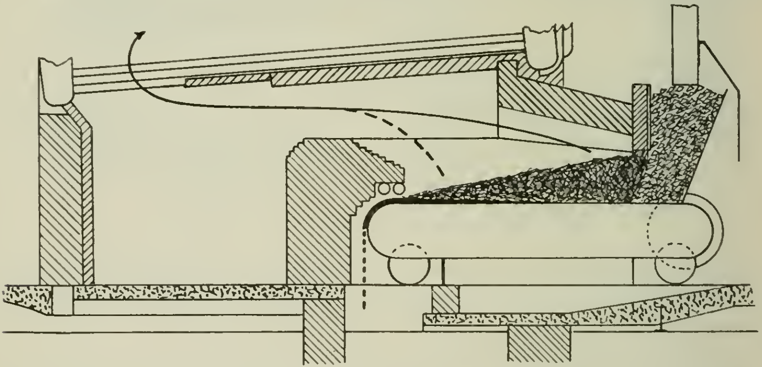


Fig. 18. Furnace and Stoker with thick fire.

Such coal as described in Table E, owing to the large percentage of small size, does not make a very good fuel bed, because it cakes together more or less, forming compact masses of coke which are more or less separated, allowing air to enter between. But such coal contains the greatest quantity of heat to be had for the money in this market; therefore it is the most desirable fuel for steam making, provided it can be used to advantage.

If this scheme of thick fire on a chain-grate in such furnace as the tile-roof, is studied, it appears as a means of equalizing the effect of all of the irregularities of the fire. As shown by the arrows in Fig. 18, the gas from the back (containing unused air) meets with the gases from the front (containing unused volatile combustible) and they join as an ideal finished product, provided the ingredients are supplied to the grate in the proper relative quantities.

The grates and furnaces served by the four large chimneys shown in Fig. 15 are the only examples of "smoke proof" apparatus with which the author is familiar.

The foregoing has dealt principally with the chain-grate located in a furnace, and it is now in order to examine the performance of the grate without a furnace. Such apparatus is shown in Fig. 2. As illustrated, a portion of the volatile combustible matter flows from the front of the grate and escapes, without mixing with the large excess of air from the back. What this loss may be is indicated in the test between the Babcock & Wilcox and Heine boiler No. 1, the essential features of which are as follows:

	Babcock & Wilcox..	Heine No. 1.
1. Efficiency of combined boiler and furnace	57.83	59.12
2. Efficiency of boiler..	77.69	70.12
3. Superior efficiency of boiler	7.57	....
4. Superior efficiency of furnace		8.86

Item 1 includes all losses except that of combustible in the refuse, all other losses except hot gases and combustion being the same for each apparatus.

Item 2 is the measure of the cooling effect produced by each boiler.

Item 3 is the difference in cooling effect produced by the two boilers. The superiority of the tile-roof furnace under the Heine boiler is due to complete combustion, the loss by escaping volatile combustible with the Babcock & Wilcox being 8.86 per cent. Larger air supply is effective in reducing this loss, but the magnitude of the loss from the resulting greater quantity of unused air, overbalances the combustion gain. This is illustrated by Fig. 19. The formation of the curve is based on the results of the test with the Babcock & Wilcox boiler and furnace, as shown by the point of 8.86 per cent; the other point is based on the assumption that with air in excess to the extent of 870 per cent this loss would be zero. Therefore if it is assumed that air in excess could be reduced to zero, it would result in about one half of the volatile matter of ordinary coal being lost.

From the curve of loss owing to unused air, it appears that the percentage of excess may be reduced to below 80 to advantage, from which it appears to be an economical measure to produce incomplete combustion for the sake of reducing excess of air. This is true; in fact, with a chain-grate under such type of boiler, it is impossible to reduce the excess much below 80 per cent under most favorable conditions. As escaping volatile combustible results in smoke with such type of apparatus, smoke production and highest attainable heat efficiency go together, and one may judge of efficiency by the appearance of the chimney. The character of the coal has a most important influence on the amount of escaping volatile combustible. For example, ordinary screenings form a more or less compact mass, preventing to a large extent entrance of air to all portions of the fuel bed; for this reason there is but poor mixture between fuel and air at the grate. With washed coal of a uniform and desirable size, results are very much better; in fact, even unwashed coal of corresponding size produces an improvement. The reason is that the openings between the pieces of fuel are sufficient to allow air to penetrate largely to all portions of the bed, thus assuring a better condition, because less volatile combustible escapes. And because of more thorough contact between air and fuel, a larger amount of coal is burned; for this reason air leakage from various sources is proportionately less. Therefore, the use of washed, or properly sized coal, will result in greatly reduced volume of smoke, over ordinary screenings. But with each

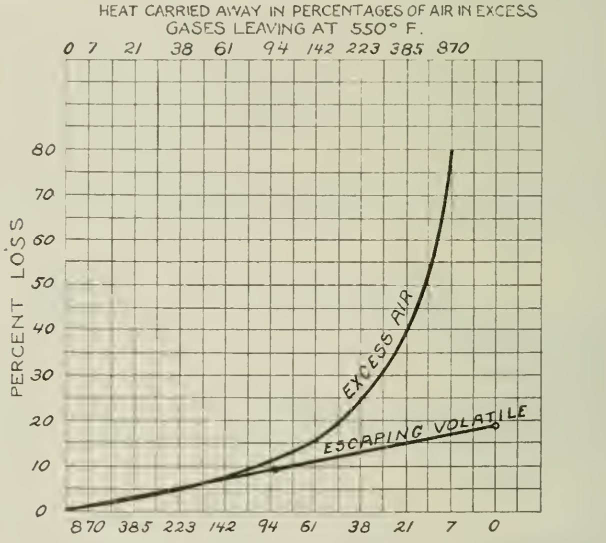


Fig. 19. Diagram Illustrating Combustion Losses from Chain Grate Stoker.

kind of fuel, the maximum amount of smoke indicates maximum heat efficiency. This type of apparatus is considered as being suitable for the use of "cheap fuel," an example of which is given in Table E. It is made for that purpose; specified by engineers, and purchased with the understanding that it will insure a realization of such hopes, and the result is that disappointment is often experienced.

It is sometimes believed that a thin fire is of economical advantage, and an effort to improve conditions by such means is adopted, with disastrous results as far as economy is concerned.

The improved boiler, and suggested chain-grate, together with the tile-roof furnace, afford means of obtaining an ideal efficiency. But the present demand is largely for an apparatus that will produce superheated steam, and with the Heine boiler there is no adequate location for a superheater. With the Babcock & Wilcox, however, there is an ideal location, as shown in Fig 6. The gases coming in contact with it after having passed through the boiler once, are at a temperature low enough to avoid damage to the pipes, and yet high enough to do efficient work. That the improved boiler may be equal in this respect to the Babcock & Wilcox, requires that it be equipped with a superheater located between the first and second gas passes, so that it will be acted on after the drop in temperature of the first pass has occurred.

DISCUSSION.

Mr. W. L. Abbott—The importance of this question of burning coal is being impressed upon the large power producers more and more every year. Formerly, in large power plants, the largest, or at least a very large part of their expense was that of labor; but with larger units and greater demands for power, the necessity of labor has diminished relatively, very materially, but the requirements for fuel increase in proportion to the requirements for steam. In other words, we are making very little progress in the improvement of our steam producing apparatus.

This paper of Mr. Bement's points out some of the reasons why we are not getting the results in plants that we are getting on paper; and why we do not get the results every day that we occasionally get with tests.

I think Mr. Bement is a little severe in his strict definition of the word "furnace;" at least some people would think so. We used to think that almost any place where we can burn coal is a furnace; but there should be a distinction made between a place to burn coal and a place to burn coal properly. When we see coal going to waste in the ash pit, or when we see steam going to waste through the safety valve, someone is called to account very promptly for it. But if we can see stacks running like those illustrated in

Fig. 15, and without much waste in the ash pit or much steam wasted at the safety valve, most everybody would be very well satisfied. As was pointed out in the paper, it is possible to run chimneys like that, burning 20 tons of coal an hour or more, and still not be producing any steam—simply using the heat of the coal to warm up the cold weather.

Fig. 6 is a curve, which to me is very interesting, showing the drop in temperature of the gases passing through the Babcock & Wilcox boiler. That temperature comes down to within, I suppose, 125 deg. or so of the temperature of the steam,—though perhaps not quite so close. The performance of the Heine boiler, with which this is compared, shows that if that curve is cut off about one-third of the way from the final end of it, we reach the final temperature of the gas with the Heine boiler; which has the same number of square feet of heating surface. It goes to show that there is that much greater proportion of the heating surface of the Babcock & Wilcox boiler brought into service than there is in the Heine boiler.

Fig. 7 illustrates how the gas is short-circuited through the boiler and what great proportion of the heating surface of the boiler remains inactive or nearly so.

The paper brings out several points very prominently, and suggests at least two or three points, along which lines great improvement might be made in boiler and furnace practice.

Mr. C. H. Hurd (by letter)—I have read Mr. Bement's paper with considerable interest and I believe the data here presented will prove itself to be exeedingly valuable, to the Society in general, and especially so to those who are engaged in the problems of economy in connection with steam production.

The paper is of unusual importance since the author has confined himself in each argument to a single set of conditions, as frequently, in investigations of this nature, we try to solve too many problems with one set of experiments. Up to the present time most of the work along this line has been carried on by the boiler builders, and in their desire to produce a construction which will fit all kinds of service, it is not surprising if they fail to a certain extent in any special case. The prevailing idea in regard to baffles is to reduce the velocity of the gases through the boiler. It will be noted in this case that this has not been done, but rather by decreasing the sectional area of each pass they have increased the velocity; and as the length of travel has also been increased, the time required for the gases to pass through the boiler remains practically unchanged. Therefore, the gain in this particular instance is probably not due so much to the length of time in which the gases remain in the boiler as to the more effective manner in which they are presented to the entire heating surface.

Mr. Bement's statement regarding the definition of boiler efficiency, I believe also is timely and to the point. It is recognized among engineers who are conversant with the subject that we are in need of a better standard for the proper comparison of boilers, and in view of the difficulties which present themselves when we try to test several boilers under identical conditions, it would be a matter of very great convenience if we were able to apply such a table of co-efficients. As a matter of fact, the "boiler efficiency" as usually reported, is not the efficiency of the boiler at all, but the efficiency of operation. As recommended by the latest code of the Am. Soc. Mech. Engrs., a complete report should always be accompanied by a heat balance. In order to do this, it is just as necessary to measure the quantity of air or gas, either directly or indirectly, as with the fuel and water.

At Fig. 4, the author shows three curves representing the final temperature at various degrees of initial temperature. Of these, probably curve "C" is of the greatest importance since it shows a boiler under actual working conditions. It would also have been of interest to have had a fourth curve showing the efficiency of this boiler. It will be noted in the range between 1200 deg. F. and 2200 deg. F. that there is a drop in final temperature of about 60 degrees. While this is not quite as much as we usually get in practice, nor nearly as much as would be calculated from Donkin's formula, assuming the boiler to be working at about rating; yet it shows a very important feature in this connection. It there were no losses from radiation, it is evident that the operating efficiency would be represented by $\frac{1200-720}{1200}$ or 40 per cent (in the case of 1200 degrees initial temperature) and $\frac{2200-600}{2200}$ or 70 per cent, in the case of 2200 degrees final temperature. I point this out to illustrate that while the final temperature may remain very nearly constant for various conditions, the efficiency depends principally upon the temperature of the furnace.

I believe the author's criticism regarding the use of chain grates under Babcock & Wilcox boilers (Fig. 2) needs some modification, as the difficulty which he mentions can be largely overcome by raising the boiler considerably above the grate. Then, if the "bridge wall" and the igniting arch are properly constructed, there is no reason why we should not get a high efficiency with a vertical as well as a horizontal "furnace." Also, practically the same results can be obtained by placing a damper both below and between the grate directly on a line with the edge of the igniting arch. The function of this is to be able to regulate the air between the thin bed of coke and the thicker bed of freshly ignited coal. Then by controlling the air for these two portions of the grate, the loss on account of the fire burning "short" will not only be diminished, but the effect of carbon mon-oxide and excessive air passing off together will be reduced to a minimum.

I believe Mr. Bement deserves a great deal of credit for bringing these matters before the Society.

Mr. P. Junkersfeld—There is one point brought out in the paper, and again emphasized by Mr. Hurd, which to me seems a very important one; that is, the fact that most all work of this kind has heretofore been done by the boiler manufacturers. They are naturally interested in developing one type of boiler and one type of boiler setting that will meet the largest possible number of conditions. It is their interest to do so. Mr. Bement, in his experiments, has shown us I think, very conclusively, that under the particular conditions at least, he has found a very marked improvement. The question might be asked, why did not the boiler people find that out before? But under different conditions of draft and boiler setting different results are obtained. Under some conditions, in Mr. Bement's experiments, it was necessary to increase the draft and bring it up proportionately. The point I wish to make is that the matter has been studied carefully to secure the best operation for each individual plant, as seldom there are two cases just alike in all particulars.

I would like to ask Mr. Bement what his method is of determining the various temperatures, what degree of accuracy he feels he has secured, and whether or not he has experienced any particular difficulty in securing reliable results?

Mr. Abbott—Referring to what Mr. Hurd said in his discussion about the baffles being for the purpose of increasing the velocity of the gas, as shown in Fig. 2 of Mr. Bement's paper, if it were possible to cut off the excessive air from the thin part of the fire, it would certainly be very desirable.

Prof. P. M. Chamberlain—In view of the frequent changes, rearrangements and improvements in furnaces, the question naturally arises, has the art of coal burning gotten to the scientific stage when a furnace can be designed with assurance of getting all the heat from a given coal?

Mr. Abbott—I do not give so much weight to that question as some do. I think that with an ample stack of sufficient height we should be able to tell beforehand how much draft we are going to have. Knowing the grade of coal we are going to burn, we should know pretty nearly what the results would be. We never have too much draft in the stack. If there is too much in the fire, it can be easily reduced, and that is the main question—whether you have draft enough. If you have too much, you can cut it down to what you require. Personally, I think that it should be easy to determine beforehand what the results should be with almost any setting.

Mr. George Welsby Scott—Referring to Fig. 1, while the two additional horizontal baffles and the consequent two additional horizontal passes introduced by Mr. Bement may serve to bring about a greater degree of contact of the gases with the water tubes than is obtained in the ordinary arrangement of the Heine boiler, it is evident that such action will involve associated results not altogether in the line of operative economy. One such result is a direct loss in draught, and hence for any given conditions, a direct reduction in the air supply, and the consequent limitation with regard to capacity in this respect. Concerning this point, I would ask Mr. Bement if practically the same results could not be obtained by the more simple means of using a fairly well-fitting damper in the uptake of the flue, or by reducing the exit area in the upper baffle of the regular Heine arrangement? If the simpler means referred to should prove to be the economical equivalent of the arrangement shown in Fig. 1, there would be no occasion for the added structural difficulties involved by the use of the additional baffles shown in Mr. Bement's arrangement.

I would also ask Mr. Bement if in his special work in connection with the operation of steam boilers, he has observed that, other things being equal, the boiler which is fired the hottest—that is in which the furnace gases are at the highest temperature, even though the final or tail gasses may be also relatively high—produces steam for the least cost in fuel?

Mr. Abbott—Personally I have noticed that the higher the initial temperature, the lower the final temperature. The reduction of the initial temperature can be brought about by an excess of air. I have not regarded it as probable that you could have a high initial temperature and high terminal temperature also. I would like to have Mr. Bement discuss that point a little in his closure.

Mr. Scott—In this case I referred to boilers operating at or about commercial rating; or, if it will make the point clearer, I would ask, is it not a fact that other things being equal, the boiler which produces more steam, and thus gives out more horse power, does so with less cost per 1000 lbs. of steam than one operated less vigorously?

Mr. Abbott—In that case it is true to some extent, where you are burning more coal than possibly the boiler was designed for.

M. J. P. Johnston—Referring to page 14, Mr. Bement states, "It is observed that the combustible gases and air do not come in contact to a sufficient extent to mix with each other, but flow in unmixed condition among the tubes of the boiler," etc. I would like to ask if he has made any tests to show that this is so?

Mr. W. L. Goddard—We have been making some experiments lately at the McCormick Twine Mills, which have given some interesting results.

The experiments have been carried on during the last two months. What we have done, was to convert a Babcock & Wilcox type of boiler to a Heine type—Fig. 20.

Several years ago, I improved the steaming capacity of some Heine boilers by introducing vertical baffles, as shown; we found the same conditions existing in this case, as in Fig. 12; the gases took the direction illustrated. Upon placing a piece of lath in he back upper corner among the tubes and in the front lower corner, we found that it would remain there several hours and be hardly charred. We came to the conclusion that the heat was not reaching these corners of the boiler, and that these parts of the boiler were not doing any work. After the vertical baffles were introduced there was no more trouble about lack of steam. In the boiler we are now experimenting with, we removed the vertical baffles and put a tile roof over the furnace, and over the top row of tubes. We have been operating the boiler in this condition for over six weeks, and we get an intensly hot fire, and while we have not made any accurate tests, we are satisfied that this boiler is doing more work than others we have. We have determined this by filling this and the other boilers in the same battery to the same height; then closing the feed pipes tight on each, the water will go down the soonest in the boiler with the tile roof furnace. We are having trouble with the tile roof burning out. If we can find a tile that will endure the intense heat, we believe we will have made an improvment.

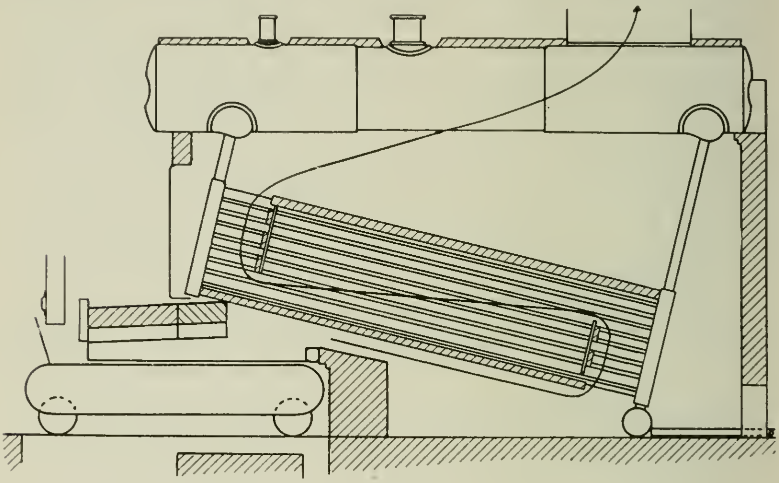


Fig. 20.

Our point is, that we have made a "dutch oven" furnace and placed it under the boiler; we did not have room to place it in front as we would liked to have done, so we did the next best thing.

Last Sunday we burned fifteen tons of coal under this boiler, in twelve hours; the coal was "No. 2 Nut," from the Odin district, Illinois. The boiler was probably doing double its rating as it takes five hundred Boiler H. P. to heat our building. We had no trouble in keeping up steam, and at no time did we see any smoke coming from our chimney.

Mr. Abbott—To what do you attribute your increased efficiency?

Mr. Goddard—To a hotter furnace.

Mr. J. E. Bond—To what do you attribute your hotter furnace?

Mr. Goddard—It is a "dutch oven" and I do not know of any better furnace than such. It is the hottest type of furnace you can get, and it keeps the fire from the tubes until combustion has a chance to take place.

Mr. J. E. Bond—I have been experimenting in locomotives along the same line, and think an excessively hot furnace is due to ignition of the hydrogen gas. At least I think that is the reason. Carbon burns at comparatively low temperature, and consumes about 12 pounds of air per pound of combustible, and with perfect combustion gives about 14,000 British thermal units. Hydrogen I believe burns at high temperature, requiring about 1,600 deg. F. to ignite, consumes about 36 pounds of air per pound of combustible, and gives with perfect combustion about 62,000 British thermal units.

By having the baffle plate spoken of, you will have the high temperature necessary to ignite the hydrogen, the gases which would otherwise pass off through the stack.

Mr. Abbott—As a matter of fact, the hydrogen which exists in these gases is not free but is in combination as hydrocarbons, and I believe that when they are broken up, the hydrogen will burn first, and what goes away is usually carbon monoxide or soot, if there is not oxygen enough to burn it all. I would explain the higher temperature in that case by the fact that the hydrocarbons do burn, and you get the additional heat from them.

Referring to Fig. 6 of Mr. Bement's paper—the curve showing the temperature obtained in the Babcock & Wilcox boiler—the final temperature was very much lower than with the Heine boiler; nevertheless, the efficiency of the Heine boiler was greater than that of the Babcock & Wilcox boiler, because of the fact that these gases were all burned before they reached the cold tubes. The Heine boiler, although it has only about two-thirds of the capacity for cooling off an equal amount of gas as the Babcock & Wilcox boiler, has exceeded in efficiency the Babcock & Wilcox boiler, because of the fact it had under it what Mr. Bement calls a furnace. I think it is possible, on account of obtaining such good results in comparative tests with the Babcock & Wilcox boiler, that the Heine people have been satisfied with their baffles as they have made them, perhaps not realizing that their success was caused by having facilities for a hotter fire, and what they lost in hot gases, the Babcock & Wilcox boiler more than lost in unconsumed gases.

Mr. Geo. M. Mayer—I would like to ask Mr. Bement whether in his opinion the arrangement of the baffle plates of the Babcock & Wilcox boiler is not better than in the improved Heine boiler, by using vertical baffle plates, so that the gases impinge on the tubes instead of sliding along. The Heine boiler showing a larger efficiency by a small amount, it would seem that there is an apparent gain in the gases crossing the tubes, inasmuch as the improved Heine boiler has the furnace—so-called by Mr. Bement—while the Babcock & Wilcox boiler is without this improvement?

Mr. Abbott—That is a very interesting question, and it is a talking point with the Babcock & Wilcox people that the gases in their boilers, crossing the tubes at right angles, give up more heat than if flowing parallel to them.

Mr. F. K. Vial—We are figuring on fitting up a boiler something similar to what Mr. Goddard has shown. The reason is the size of the boilers is so small, we did not have room for the successful baffling that you have in the larger boilers. The special boilers in which I am interested are only about six tubes high, and therefore it would be impractical to make the three passes. We could use the baffling as shown in Fig. 20, which seems to me to be a very practical suggestion, as the heat comes in contact with all parts of the tube.

I would like to ask if any damage is likely to accur to the lower tube on account of the encircling tile, and if, on account of the intense heat which the tile receive, there might not be some objection from the boiler inspectors?

Mr. J. C. Bley—Referring to Fig. 8. The text speaks of line Y; I would like to know if that is the vertical line, and if so, at what point across the width of the boiler the measurement is taken? Were they taken near the centre of the boiler horizontally, or at one side of the centre?

Mr. Abbott—Near the centre; beginning at the bottom and then reaching up.

Mr. Bley—Since you have had such success in baffling so far, why not carry it further? In that connection, I suppose there would be one difficulty if you run it too far—viz., the passages would choke up and you would have difficulty in cleaning them out. How often do these baffle passages need cleaning out in order to keep them in working order?

Mr. Abbott—The ones referred to have been in a year and have not yet been cleaned.

Mr. Bley—Do you think you could put in twice as many as you have now and have twice the result?

Mr. Abbott—Yes.

Mr. Bley—Three times as many?

Mr. Abbott—Yes, I think so, if there is draft enough. In this case we do not have any soot; some ashes go up, but the flame is burned out before it gets to the boilers, so there is nothing that you would call soot. It is automatic, and is due to the construction of the furnace; it makes no difference whether it is a good or poor fireman, there is never any smoke; I have never noticed it even on a green fire.

Mr. Bley—On looking at the diagram of the Babcock & Wilcox boiler as compared with the Heine boiler, would the question of the circulation of the water in the boiler be an important item? I suppose the efficiency of the boiler was based on the amount of steam it produced. In the Heine boiler the water legs admit of the circulation of the water through the tubes much more readily than the pipe connections of the Babcock & Wilcox boiler, and I would like to inquire whether that difficulty has been noted in the different boilers under the same management.

Mr. Abbott—That is a very vital question in some cases.

CLOSURE.

Mr. Bement—Mr. Hurd's explanation of the reason for the higher efficiency of the boilers with greater length of gas travel is interesting, and probably to a large extent true. I gave the reason as owing both to more time and exposure to greater amount of boiler surface. The velocity is not in proportion to reduction in area, because with the improved boiler, compared with the Heine, draft at the fire was reduced about one-third. According to Fig. 7 it would appear that the gases flow in the Heine boiler through a small area. The reason is probably owing both to greater interval of time and exposure to more boiler surface.

Curve C of Fig. 4 is the proper one to illustrate the effect of the initial, or final temperature; but its determination is a diffiult matter, requiring uniform heat generation at different temperatures. If this curve had been determined it would have shown that the final temperature is not constant, as I have assumed, but higher with the lower initial, and lower with the higher initial temperature; but as it is desirable to illustrate the effect of the entire range of the initial temperature, I employed the conservative assumption that the final is constant for usual working conditions and to show that my assumption is permissible, curve A was determined—the strongest obtainable evidence to the contrary—the formation of which was influenced by rapidly increasing quantity of heat, accompanying increasing initial temperature. For example, with 2,200 deg., the fire was eight feet long, and with 400 deg. initial temperature, the fire was about eight inches long.

A vertical furnace of sufficient height would cause complete mixture of the gases, but would be an inconvenient and expensive form of construction, requiring that the boiler be located at least 16 feet above the grate to secure the same result had with the horizontal furnace.

If the air supply could be proportioned to the different thickness of fire on the grate, by an arrangement of adjustable dampers, very much better mixture between fuel and air could be had at the grate, but such would be a complicated device requiring delicate regulation. Herein lies the difficulty, as it is now almost impossible to get present apparatus operated properly.

The final temperatures for the Babcock & Wilcox and Heine No. 1 were measured with an electrical resistance pyrometer. Those of the improved boiler and Heine No. 2 were measured with high range thermometers. Comparison of these were made with a special standard thermometer made for the purpose of these tests, all values being based on the standard instrument.

Temperature measurements shown in Figs. 6, 7, 8 and 9 were made with a thermo-electric couple, those in the Babcock & Wilcox boiler at the time of the regular test. Measurements in the Heine boilers Figs. 7, 8 and 9 were independent of the regular tests; others not shown were made; the time devoted to this measuring was 40 hours, some of the points being based on averages of as high as 50 determinations. No difficulty were experienced, and every precaution against error adopted. The accuracy of the work is without question.

I consider it possible to design apparatus of very high efficiency; the improved Heine boiler has proven itself to be such, and the improved chain grate described when located in a furnace, certainly fulfills the requirements for very efficient combustion.

It would be desirable to employ a refractory material of greater resisting power than fire brick, for the furnace roof-tiles, if obtainable at a reasonable cost; there is a possibility that the material known as siloxicon may be available for this purpose. The fire brick tiles however, give no trouble when properly made from good material, and have a long life.

Good heat efficiency with any apparatus is dependent on proper operation, and this is a whole problem in itself. Formerly it was my principal effort to induce people to operate the apparatus that they had to best advantage, but after further study and experiment, I find that large improvement in present apparatus is possible.

Capacity is dependent on the flow of air through the fuel bed, and is governed by the strength of draft, also by the resistance offered by the fuel. For example very small sized coal offers greater resistance than larger size, and therefore requires stronger draft. If uniform capacity is to be maintained, the draft at the fire must be regulated according to the resistance of the fuel bed. A very strong draft ensuring a certain reserve power is very useful, but as far as economy is concerned, it is a dangerous thing to put under the control of most owners and operators, because it is the prevailing custom to always use the full draft whether necessary or not. A strong draft is responsible for greater heat losses than often realized, owing to its increasing the excess of air, due to the fuel supply not being sufficient for the air supply.

This proposed chain grate will not of itself operate to the best efficiency, since the draft must be regulated to suit the fuel bed, and this requires that a draft gauge be attached to each furnace. If the available draft is not sufficient to give the required capacity an auxiliary means, such as forced draft, may be employed.

As showing the variation in size of coal received as $\frac{1}{25}$-inch screenings I have prepaped table No. 1 from the laboratory records.

TABLE NO. 1.—SIZES OF COAL.

SIZES OF OPENINGS IN SCRFENS.	PER CENT OF COAL PASSING THROUGH EACH SIZE.					
	A	B	C	D	E	F
0.25	68 2	60.7	48.0	20 0	22 0	29.0
0.50	9.8	13.7	20.0	30.0	12.0	10.0
0.75	9.4	9.3	24.0	20.0	20.0	12.0
1.00	7.4	8.9	8.0	20.0	20 0	13.0
1.25	5.2	5 9	0.0	10.0	20.0	15.0
1.50	0.0	1 5	0.0	0.0	6.0	14.0
1.75	0.0	0.0	0.0	0.0	0 0	7.0

Sample A is an example of a small sized coal, while F is one of large size, and D one of very desirable mixture, neither too large nor too small. This coal is all of the same geological character and from the same locality; there is but slight difference in moisture and ash, and heating power in consequence, differs not to exceed 10 per cent. In one of the furnaces of the plant in question coal A would produce not to exceed 300 H. P., while that shown by D would make as much as 600 to 700 H. P., with the maximum obtainable draft in each case. Now it is obvious that the coal A would require a stronger draft to burn the same quantity in a given time as would be the case with coal D. When it is realized that the size of coal as shown in Table No. 1 may, and does change from hour to hour, the necessity of properly proportioned conditions is of vital importance.

It must be understood that for high furnace efficiency to be attained, requires not only a good apparatus, but means for its proper manipulation.

Mr Scott presents some interesting and important questions regarding the effect of the changes made in these boilers, and I will explain the effect fully.

The chain grates replace another type of furnace, under a portion of these boilers, with the result that the bottom row of tubes of the Heine boilers rapidly burned out and failed, owing to the bottom half of the tubes being exposed to the fire for their full length as illustrated by Fig. 14. These tube failures were not only inconvenient and dangerous, but very expensive. The cause was that the water supply capacity of the tube itself was not equal to the quantity of heat supplied to it. The application of the encircling tile, Fig. 14, was a complete and satisfactory remedy of very great value.

The effect of the added horizontal baffles was to increase capacity and efficiency; reduce draft and coal burning capacity, as shown by Table No. 2, which contains data from the report of one of the tests between the improved and unimproved Heine boilers. The size of coal used in the tests was rather small; for this reason the capacity was not large. These two tests were run at the same time, one being started fifteen minutes in advance of the other. Coal from the same bunker was used on each grate, alternate wheel-barrow loads, being delivered before each boiler and only as required. The boilers adjoin each other in battery. The dampers were full open, and each apparatus was forced to the maximum attainable capacity which however as stated, was not great on account of the size of the coal. It will be observed that while the draft is reduced, the effect of the improvement is to increase the capacity as well as the efficiency. The amount of heat generated was largest with the Heine apparatus, but the absorbing capacity of the improved boiler was sufficient to recover a greater quantity, although its available supply was less. Therefore instead of this improvement reducing capacity it increased it.

TABLE NO. 2.—TESTS OF BOILERS.

		HEINE BOILER.	IMPROVED BOILER.
(1)	Sqare feet of heating surface	4,800	4,800
(2)	Square feet of grate surface	72.2	72.2
(3)	Pounds of combustible burned per hour	1,765.75	1,446.56
(4)	Heating power of combustible B. T. U. per pound	13,201	13,201
(5)	Pounds of water evaporated per hour	13,210.34	13,629.24
(6)	Temperature of feed water degrees F	212	212
(7)	Temperature of gases final, F. degrees	594	442
(8)	Temperature of gases final above air F. degrees	514	362
(9)	Temperature of gases final above steam F. degrees	217	65
(10)	Temperature of steam F. degrees	377	377
(11)	Draft over fire, inches of water	0.38	0.22
(12)	Horse-Power	382 91	395.05
(13)	Pounds of water evaporated from and at 212 F. per pound of combustible burned	7.47	9.42
(14)	Efficiency, per cent of heat absorbed by boiler	54.64	69.60
(15)	Fuel saving due to improvement, per cent		21.40

There are no structural difficulties in connection with the inserted baffles, the temperature at their location is not high enough to have any influence on their life, and their presence occasions no difficulties whatever.

In reference to the effect of increasing the length of the upper baffle of the Heine design, so as to cause the gases to flow nearer to the front water leg at the point of exit, I had the baffling of one of these boilers increased as Mr. Scott suggests, and while the result was of course beneficial to some slight extent, it was not enough to be discovered. Later the Heine Boiler Company engaged Mr. J. J. DeKinder to examine into the matter. He had the tile roof and the upper baffle of one of the Heine boilers removed, and replaced with fire clay, to ensure that there should be no leaks; at the same time their length was increased as Mr. Scott suggests. Mr. A. C. Wood then made tests for the boiler company, the result of which corroborated the tests of the Chicago Edison Company.

Partly closing the damper of the Heine boilers would result in increased efficiency, but would be accompanied by reduced capacity, a matter of serious importance in the case in question. A plant can not operate without sufficient capacity, but may do so at low efficiency.

To the question whether the highest heat efficiency in general practice, is accompanied by correspondingly high final temperature, the answer is that it does. The reason is that in the large majority of cases, too much furnace capacity is employed; this makes it impossible to supply sufficient coal to utilize the air supply to best advantage without more steam being made than required; this results in low initial temperature, and consequently low efficiency. If some of the units are shut down and the load carried by a smaller number, it requires that they be fired harder, causing a rise of both initial and final temperature, but the rise of the former is very much more than the latter. This is illustrated by curve A of Fig. 4. It is observed that both temperatures rise together. The final by 62 per cent and initial by 425 per cent for the range of measurements. It is not the final, but the difference between the initial and final temperature, which controls heal efficiency. Therefore it is apparent that if initial temperature should be 1500, and final 500, and an increase of final to 600 is accompanied by initial increase to 2500, that the latter would be the more efficient condition.

If however, maximum initial temperature prevails, and the quantity of heat generated is increased, by burning more coal—due for example to stronger draft—the final temperature will rise due to resistance of the heating surface, while the initial remains constant.

If the quantity of heat generated remains constant, increase of initial is accompanied by decrease of final temperature; or if initial decreases it results in increase of final temperature.

A poor boiler with a good fire under it, will give better results than a good boiler with a poor fire, but with the same fire under each the good boiler will produce the lowest final temperature and consequently the highest efficiency.

Mr. Scott, of course, does not imply that because the Heine produces higher final temperature than the improved boiler, that it is more efficient, because it would be denying the truth of the important law of thermodynamics, as expressed by the equation.

$$\text{Efficiency} = \frac{T1 - T2}{T1}$$

In answer to Mr. Johnson I will say that the escape of combustible gases is proven by analysis, by the corroding of an exposed platinum wire, and by the smoke from the chimney. In the test of the Babcock & Wilcox boiler it amounted to 8.86 per cent of the heat charged to the boiler.

It will be observed that Mr. Goddard has changed his Babcock & Wilcox type of boiler to a Heine for the purpose of enabling him to use a furnace.

In answer to Mr. Mayer, I have not determined whether there is any advantage in gas travel across the tubes, as compared with that parallel with them; if there is it is probably very little. The two methods have an equal number of advocates.

In reference to Mr. Vial's inquiry I will say that no damage to the lower tubes is caused by the encircling tiles; on the contrary their presence is of enormous protective value.

The line Y, about which Mr. Bley inquires, is a vertical one at the middle of the boiler.

I do not consider it advisable to carry the baffling to any greater extent than that employed, because the consequent reduction in capacity would overcome the slight gain in efficiency. When gases leave at 65 to 94 deg. above steam temperature, there is but slight possibility of the boiler extracting more heat. If this should be done however, they would not fill up with soot, because there is no smoke, and they could not be obstructed by fine dust of the ash, because the draft would not be strong enough to carry it out of the furnace. With the present arrangement there is no trouble from the passages filling up; the surface of these boilers is blown off by a steam jet, just the same as any water tube boiler.

In reference to the comparative areas for water circulation, those of the Heine are superior to the Babcock & Wilcox, but it does not appear that this fact has much if any, effect on heat efficiency.

Following a suggestion of mine, Mr. C. A. Hurd has made some tests to determine the effect of different strength of draft on efficiency and capacity, with a 300 H. P. Babcock & Wilcox type of boiler served by a chaingrate stoker. I am indebted to him for the following data, and for the graphic illustration shown in diagam Fig. 21.

The different performance is given in Table No. 3. The thickness of fire was 7.5 inches, the coal was an average Illinois screenings of fairly uniform size.

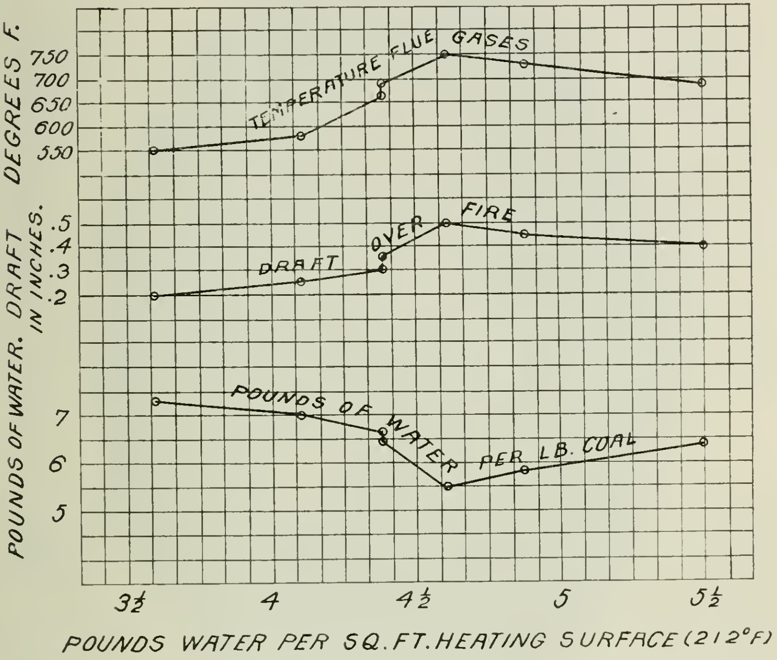


Fig. 21.

From the above I have prepared Fig. 22, wherein capacity and efficiency are plotted in their relation to draft. The maximum strength of draft in this plant, containing a large number of similar units, is 0.5 inches of water at the fire, and it had been the custom to keep dampers full open; this resulted in capacity shown by

TABLE No. 3.

EFFECT OF STRENGTH OF DRAFT ON PERFORMANCE OF BABCOCK & WILCOX BOILER WITH CHAIN GRATE STOKER.

Draft at fire, inches of water.	H. P.	CO_2	Final Temperature.	Evaporation.	Efficiency.	Water pr. sq. ft. of H. S.
.2 0	315	11.1	555	7.3	70.0	3.6
.2.5	350	10.4	575	7.0	68.0	4.1
.3.0	400	10.0	675	6.7	65.0	4.4
.3.5	400	9.0	685	6.5	62.5	4.4
.4 0	478	8.4	685	6.4	61.5	5.5
4.5	426	8.0	730	5.9	57.0	4.9
.5.0	402	7.5	750	5.5	53.0	4 6

point A and efficiency of 53 per cent. The simple reduction of draft transferred practically the same capacity to point B, and increased efficiency to 65 per cent. It is interesting to observe that capacity

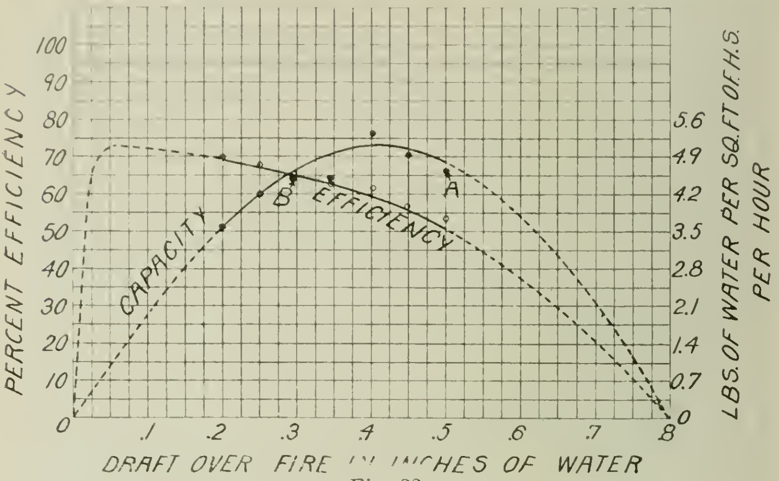


Fig. 22.

was increased by reduction of draft, the maximum being at 0.4 inches of water. In the extension of the curves, it is assumed that capacity and efficiency would drop to zero at 0.8 inches of draft; this point, however, would be governed by the size of the coal. It will be observed that there is an apparent inconsistency in some of the points of the capacity curve; this cannot be taken as an indication of error, because varying size of coal will produce such result.

GEORGE SHATTUCK MORISON.

A MEMOIR.*

The late George S. Morison was a born Engineer. His father was a Unitarian minister, of Scotch-Irish stock which originally settled in New Hampshire, but the son was born in New Bedford, Mass., December 19th, 1842, and spent much of his boyhood at Milton, near Boston. He was prepared for college at the Phillips Exeter Academy and graduated from Harvard in 1863. He planned for himself a legal career, studied law, received the degree of LL.B. in 1866, and was admitted to the New York bar the same year.

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* Prepared by Messrs. O. Chanute, H. W. Parkhurst, E. L. Corthell, A. Noble, R. Modjeski and E. Gerber.

But he found that he had made a mistake, as all his instincts were towards mechanical constructions. He had conceived a strong dislike to the law. He considered it a heterogeneous mass of precedents through which cases were more often determined upon former decisions than upon their abstract merits. The equity branch is the only one he would have cared to practice, but the building of public works so appealed to him that he determined to throw up the law and to become an engineer.

Through his friends in Boston he was recommended to Mr. Jas. F. Joy, of Detroit, Mich., who was the head of the "Boston party" then extending the Michigan Central and the Chicago, Burlington & Quincy Railroad Systems into Missouri, Kansas and Nebraska, and through him he was sent, in October, 1867, to Mr. O. Chanute, who was then building the first bridge across the Missouri River, at Kansas City, for one of the "Joy Roads."

Morison started in his new profession quite without preliminary training, but he displayed such aptitude and ability that he advanced very rapidly, and after the bridge was opened (July, 1869), he was selected by Mr. Chanute to assist in preparing for publication an account of the construction of the "Kansas City Bridge," which had attracted some public attention in consequence of its novelty and apprehended difficulties.

From January, 1870, to June, 1871, Mr. Morison was engaged in making examinations of the character and resources of the country through which it was proposed to extend the "Joy Roads." In June, 1871, he was called to Detroit to take charge of the Detroit, Eel River and Illinois R. R. as Chief Engineer. He remained there until April, 1873. By that time, Mr. Chanute having become Chief Engineer of the Erie Railway, Mr. Morison rejoined him as Resident Engineer of the Eastern Division. The Erie Railway at that time was chiefly equipped with wooden bridges; the few which were of iron being proportioned for much lighter loadings than those of the new locomotives which it was intended to place upon the line, and Mr. Morison had an ample field for his tastes and talents in reconstructing and strengthening the bridges. He soon became the Principal Assistant Engineer, and when the celebrated Portage bridge burned down in 1875, he designed and built the iron structure which took its place, in six weeks from the date of conflagration.

He resigned from the Erie Railway in November, 1875, to become consulting expert on railway properties for Baring Brothers & Co., and was connected with them for 10 years. He had shown such individuality that his friends thought that his greatest success would be as a railroad director and manager, and he served as director, (representing the Barings) for 10 years on the Eastern R. R. of Massachusetts, 4 years on the St. Louis, Iron Mountain and Southern

R. R., 8 years on the Maine Central R. R. and 8 years on the Ohio and Mississippi R. R., the latter directorship extending to 1892.

From 1875 to 1880 he was a member of the firm of Morison, Field & Co., bridge contractors, but he retired in order to give all his attention to professional engineering. He at once took a prominent position among consulting engineers by beginning the construction in rapid succession of that long list of bridges over the Missouri and Mississippi and other important rivers which have made his name so famous.

To bridge the Missouri River in 1880 was still a great undertaking and had few precedents. His first great bridge was that at Plattsmouth, over the Missouri, and was completed in 1880. It is one of the early bridges in which steel was used to a considerable extent, the two 400-foot spans being a little more than half steel. The description given by Mr. Morison in his monograph on the Plattsmouth bridge, as to how this steel was made, is a bit of interesting history of the early development of the manufacture of the present structural steel.

Before the Plattsmouth bridge was opened for traffic, Mr. Morison had let the contracts for the construction of another bridge over the Missouri at Bismarck, North Dakota. This was completed in October, 1882.

The pneumatic foundations in these two bridges had been sunk under contracts by people more or less familiar with such work. When, however, the bridge at Blair, also over the Missouri, was begun in 1872, Mr. Morison decided to do the pneumatic work himself by day work under experienced foremen, as thereby he could control the work better, use such safety appliances as were not likely to be used by the contractors, and he hoped to achieve some considerable economy. The work at Blair proved so successful that he adopted this plan at nearly all subsequent bridges where pneumatic foundations were required. These came in such succession that he was able to transfer the pneumatic plant from one to the other, and eventually a very fine pneumatic plant was developed at a comparatively small cost to any one bridge. The Blair bridge was opened for traffic in 1883, but the problem there was by no means solved. All Missouri River bridges require more or less shore protection, but at none was the channel so fickle as at Blair, and for several years great sums of money were expended under Mr. Morison's direction for controlling the river, with ultimate complete success.

The old bridge at Omaha being overcrowded with business and rather light, Mr. Morison was called upon to rebuild it as a double track structure. The new bridge is essentially new throughout, a few of the old piers only being used for supporting the approach spans. This bridge was practically completed in June, 1888, though it was not used as a double track structure till October of that year. Before beginning the Omaha bridge, Mr. Morison had made investigations for and actually begun work on another Missouri River bridge at Rulo, Nebraska. Work on this was, however, suspended for a time and the bridge was not opened for traffic till September, 1887.

While these bridges were building, Mr Morison constructed the following on the Pacific Slope: Over the Snake River at Ainsworth, Washington. in 1883; and over Clark's Fork of the Columbia, near Belknap, Montana, in 1884.

Up to this time the superstructure of Mr. Morison's great bridges had been made partly of iron and partly of steel, the floor, intermediate posts and laterals being of iron, the remainder of steel. In his next Missouri River bridge, completed in November, 1888, at Sioux City, iron was used only in members requiring welding; all the rest of the superstructure was of steel, either Open Hearth or Bessemer. All of Mr. Morison's subsequent bridges of large size were built practically entirely of steel.

In 1887 he formed a partnership with Mr. E. L. Corthell under the firm name of Morison & Corthell. This partnership continued from May 1st, 1887, to May 1st, 1889. The Sioux City and Nebraska City bridges across the Missouri, the Cairo bridge across the Ohio, the Jacksonville bridge across the St. John's in Florida, the bridge over the Willamette at Portland, Oregon, the bridge over the Snake River at Riparia, Washington, and the Bismarck water works were built under their special direction, and the plans were prepared for the Merchants' bridge at St. Louis, over the Mississippi. The Cairo bridge was at that time the longest metal bridge in the world, the metal work being exactly two miles long.

Before the Cairo bridge was completed Mr. Morison began the great bridge at Memphis, Tennessee. It is his greatest bridge work, is nearest to the mouth of the Mississippi, and when completed had the longest truss span in the United States, and was practically second only to the great structure over the Firth of Forth, although its longest span was a little shorter than a span in the Landsdowne bridge in India. The pneumatic foundations of the Memphis bridge were really its controlling features, as they were in unusually deep water (about 40 feet), and were sunk to the extraordinary depth of 108 feet below water.

The superstructure presented many novel problems, not the least of which was the character of the material of which it was composed. On a structure of such importance, it was worth while to exercise special care in making the steel and many conferences were held with the steel manufacturers, and a specification resulted which permitted the use of Open Hearth or Bessemer steel. After several hundred tons of the latter had been rolled and it was found extremely difficult to meet the requirements, the use of Bessemer steel was abandoned, with the advice and consent of the manufacturers; that already rolled was sold for other uses, and Open Hearth steel, either acid or basic, was used exclusively. Basic steel was then in its infancy and had much prejudice against it. The specifications finally developed on the Memphis bridge have been essentially the basis of all modern bridge specifications throughout the United States. The Memphis bridge was successfully completed and opened for traffic with great ceremony on May 12th, 1892.

While the Memphis bridge was being built, Mr. Morison built a bridge over the Mississippi at Winona, Minn. (1891), and at Burlington, Iowa, he replaced the original single track bridge by a double track structure (1891). These were followed by a bridge over the Missouri at Leavenworth, Kansas, one over the same river at Bellefontaine Bluffs, Mo. (1892-3), and one over the Mississippi at Alton, Ill. (1892-3). He rebuilt the bridge across the Missouri at Atchison, Mo. (1898). This completes the list of his great bridges, of which ten crossed the Missouri, five the Mississippi, and one the Ohio. His principal bridges are described in a series of admirable published monographs. In addition to these large bridges, he built many smaller bridge and viaduct structures in every part of the United States. In the early 90's he made an examination and report on a bridge over the Detroit River, at Detroit, and was again engaged on this problem at the time of his death.

In 1889 he made an exhaustive report on the Atchison, Topeka and Santa Fe Railroad, and in the next few years reported on several other railroad projects of lesser magnitude.

He competed with others in prize designs for two bridges near Washington and was awarded a prize in each case.

Mr. Morison served on several Government Engineering Boards, viz.: The Board of Engineers upon the New York and New Jersey Bridge (1894); the Board to locate a deep water harbor in Southern California (1897); a Board to report on the betterment of the water front of New York City (1895-1897); a Board to advise the State Engineer and Surveyor of the State of New York in regard to the plans and estimates for the so-called barge canal (1900-1901); and the Isthmian Canal Commission (1899-1903). After his work on the New York and New Jersey Bridge Board, Mr. Morison prepared a paper entitled "Suspension Bridges—A Study," printed in the Transactions of the American Society of Civil Engineers, XXXVI, 359, which summarizes that work and presents some novel details. His work on the Isthmian Canal Commission may be justly considered as of national importance, and was one of the strongest influences to turn the current of favor from the Nicaragua route which had previously been most strongly advocated in the United States, to the route across the Isthmus of Panama. His labors to this end were incessant and his work as a member of the Commission was supplemented by a series of lectures of a more popular character, which attracted wide attention and had great influence in shaping public opinion.

Such is briefly his more important work. That such work required a master mind goes without saying, and when it is considered that Mr. Morison had no special technical training in engineering, but entered the field when he was nearly 25 years old, it is indeed marvelous. Nature endowed him with a strong intellect and a strong will and he made the most of them. The whole grand success may be summed up in the word "work." He had no influential friends to help him, whom he did not make himself by his indomitable energy and proven ability. He studied his work carefully and thoroughly, and the minutest detail was not too small to be worked out with the greatest consideration before it was executed. One of his rules was, that if he had five minutes in which to do a thing, he would take three if necessary to think it out, and do it in the other two.

In his work he was original and not merely an imitator or developer of existing ideas. He sought to make the best possible solution of a problem, and not necessarily a solution which had been shown to be a success under similar circumstances. He sought and had a reason for everything and had the courage to act according to his reason. He did not however, carry his originality to extremes. Every previous example bearing on a case was carefully studied, and if he found that some existing idea suited his purpose better than any other, he did not hesitate to make use of it and properly gave credit where it was due.

Nor did he fail to consider the commercial practicability of his designs. His work was no doubt of the very highest order of his time, but he did not make it of such extreme character that it could not be practically attained. It was always a little better than had been done before, but never out of reach, and thus he led in the development of bridge-building, the better standards of to-day being about up to his requirements of a decade ago.

While Mr. Morison always studied out and knew every detail of his work himself, he was careful to surround himself with a competent, faithful and conscientious staff. An indefatigable seeker after truth and the best obtainable himself, he expected his staff to be no less energetic, accurate and conscientious in their work than he, and an indolent or slovenly worker did not remain long in his service.

After leaving Detroit in 1873, Mr Morison resided in New York City for fourteen years, then in Chicago until 1896, when he returned to New York. He was a great traveler, his work calling him to all parts of the United States, the Isthmus, and Europe. His business travels were supplemented by a trip around the world, as well as smaller ones to Europe and to our Southern neighbors. He was an accurate and minute observer and this, together with his studious habits and early education, gave.him a wonderful and very extended fund of knowledge, which made him an entertaining conversationalist and a scholarly, concise writer. In engineering matters, he was a writer of note and convered a variety of subjects in a masterly way, mostly in the form of reports upon his works and papers before the engineering societies. He also found time to deliver numerous lectures before professional societies and colleges, on subjects allied to his work.

He is the only engineer ever asked to deliver the Phi Beta Kappa oration at Harvard, which he did in 1896 with marked success. The substance of this address, and of several others bearing on the same subject, has been published since his death under the title of "The New Epoch as Developed in the Manufacture of Power," in which the important influence of the profession of engineering upon the civilization and industry of the world is portrayed by a master hand. Besides his professional work as an engineer, he interested himself in many other matters of public interest.

He was for fifteen years a Trustee of the Phillips Exeter Academy and five years President of the Board, resigning as such in June, 1903. To testify to his belief, as a man of science, in the value of classical study, he began the endowment there of the Morison Professorship of Latin.

He planned and directed, as Chairman of the Building Committee, the construction of Soule Hall—a dormitory—and planned the interior arrangement of Peabody Hall—a second dormitory. A third, Hoyt Hall, was designed and built entirely by Mr. Morison. He shared equally with Professor Wentworth the cost of this building, the amount of mȯney he put into it being considered a part of the endowment of the Morison Professorship in Latin. These three building are the most serviceable buildings of the Academy. Mr. Morison was also a member of the Building Committee in charge of the construction of the beautiful Alumni Hall recently completed. It was designed under his direction by Architect Casey, of New York.

Mr. Morison was a member of the Finance Committee throughout the greater part of his trusteeship of fifteen years—and its Chairman many years. Many of the funds were reinvested under his direction, and the Academy received the benefit of his services in many ways not commonly known.

He left his mark on every side of the Academy life. He loved the school and gave much of his thought to its betterment.

The Academy had the benefit of his ability not only in its buildings, but in its funds and every part of its life which needed his aid and encouragement.

Mr. Morison became a member of the Western Society of Engineers in 1879 and served as a Trustee in 1893, 1894 and 1895. He was a member of the American Society of Civil Engineers and was its President in 1895. He was also a member of the American Institute of Mining Engineers, of the American Society of Mechanical Engineers, of the Institution of Civil Engineers (London), and of the Mexican Society of Engineers and Architects. He was an Associate Fellow of the American Academy of Arts and Sciences, and a Fellow of the American Academy for the Advancement of Science. He was a member of the Union, University, Engineers', and Downtown Clubs, of New York, of the Union Club, of Boston, and the Chicago Club, of Chicago.

With all his varied interests he found time to aid others in a quiet way, by suggestions, advice and financially if the case warranted it.

Notwithstanding the vast amount of work he had accomplished there was a greater future before him, and we may well mourn the loss of a man so useful to the whole world as was Mr. Morison. After an illness of some weeks, he died in New York on the 1st of July, 1903.

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UNDER THE AUSPICES OF

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M. T. Endicott,
Robert W. Hunt,
George B. Post,
Benjamin M. Harrod,
Elmer L. Corthell,
M. L. Holman,
George H. Pegram,
William P. Craighill,
Joseph Ramsey, Jr.,
L. B. Stillwell,
Joseph O. Osgood,
George W. Melville,
Palmer C. Ricketts,
Alfred Craven,
George S. Davison,
Hunter McDonald.

OFFICE OF THE SECRETARY,
220 West 57th St., New York City.

FEBRUARY 11, 1904.

To the President and Secretary, Western Society of Engineers,
1734 Monadnock Block, Chicago. Ill.

DEAR SIRS:—I am directed by the Committee in charge to extend a cordial invitation to the Members of the Western Society of Engineers to participate in an International Engineering Congress to be held, under the auspices of the American Society of Civil Engineers, at the Universal Exposition at St. Louis, Missouri, U. S. A., Oct. 3d to 8th, 1904, the plan and scope of which are set forth in some detail in the enclosed circular of "Preliminary Announcement."

The Committee hopes that the members of your organization will, quite generally, become members of the Congress, and participate in its proceedings either in person, or by written communications forwarded to the undersigned, on any of the subjects which have been chosen for consideration.

Yours respectfully,
CHAS. WARREN HUNT,
Secretary.

UNIVERSAL EXPOSITION, ST. LOUIS, 1904. INTERNATIONAL ENGINEERING CONGRESS.

PRELIMINARY ANNOUNCEMENT.

(February 1, 1904.)

An International Engineering Congress, under the auspices of the American Society of Civil Engineers, will be held at the Universal Exposition, Saint Louis, Missouri, U. S. A., during the week October 3d to 8th, 1904.

The Congress will be one of a series of International Scientific Congresses to be held at the Exposition under the general authority and with the co-operation of the Director of Congresses.

The development of Engineering Science during the past decade has been so rapid and has extended over so wide a field that the Universal Exposition at Saint Louis seems to be a fitting time at which to review the work of the past and obtain an authoritative epitome of present practice.

The object of the Congress is to secure a thorough international consideration of certain branches of Engineering work which have been selected with special reference to their present interest and importance.

In order to facilitate the work of the Congress and to insure the presentation of topics in a systematic manner, the Committee has prepared the subjoined list of the subjects which has been selected for review and discussion.

It is to be understood that the lists of subjects proposed is somewhat tentative, and may be modified as the details of the programme are prefected.

As a basis for discussion at the sessions of the Congress, the Committee has invited engineers specially qualified in each of the various branches covered by the foregoing list, to prepare a review of the development during the past ten years in that branch in the United States, together with a summary of present practice. Engineers in other countries, experienced in these various lines, will be specially invited to prepare similar papers presenting a review and summary of practice in their respective countries.

It is proposed to print these papers in advance, in order that a full discussion at the various sessions may be elicited without giving up any time to the reading of papers at the Congress.

All engineers in the United States and in all other countries are invited to become members of the Congress, to attend the sessions, and to take part in the discussions; or if unable to attend, to forward written communications on any of the selected subjects. It is not expected that delegates will be formally appointed, it being intended that an opportunity to attend shall be afforded to any who may wish to become members of the Congress.

The papers, together with the discussions upon them, will be collated and published in one two or volumes by the American Society of Civil Engineers.

The membership fee in the Congress will be $5 00,* which will entitle the member to participate in the Congress and to receive a copy of the published proceedings.

Membership may be secured by forwarding this fee with name and address, to the Secretary of the Committee, Charles Warren Hunt, 220 West 57th St., New York City, who will issue a receipt therefor. Each member will receive all notices, programmes, etc., issued in advance of the Congress.

LIST OF SUBJECTS:

1. Harbors.
2. Natural Waterways.
3. Artificial Waterways.
4. Lighthouses and other Aids to Navigation.
5. Traffic on Improved Waterways as Compared with Seaboard Traffic, and the Effect of this Development on Railroad Traffic.
6. Purification of Water:
    - *a.* For Domestic Use;
    - *b.* For the Production of Steam.
7. Turbines and Water Wheels.
8. Irrigation.
9. Railroad Terminals:
    - *a.* At Ports;
    - *b.* Inland.
10. Underground Railways.
11. Locomotives and Other Rolling Stock.
12. Live Loads for Railroad Bridges.
13. The Substitution of Electricity for Steam as a Motive Power.
14. Sewage Disposal.
15. Disposal of Municipal Refuse.
16. Ventilation of Tunnels.
17. Highway Construction.
18. Concrete and Concrete-Steel Construction.
19. Deep Foundations.
20. The Manufacture of Steel.
21. Tests of Materials of Construction.
22. Passenger Elevators.
23. Pumping Machinery.
24. Dredges: Their Construction and Performance.
25. Steam Turbines.
26. Electrical Power:
    - *a.* Generating Stations;
    - *b.* Transmission.
27. Naval Architecture.
28. Marine Engineering.
29. Dry Docks.
30. Ordnance.
31. Fortifications.
32. Mining Engineering.
    (Sub-Divisions under this heading not yet determined.)
33. Engineering Education.
    (Sub-Divisions under this heading not yet determined.)

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* Members of the American Society of Civil Engineers will not be required to pay this fee.

ANNUAL MEETING.

JAN. 5, 1904.

The 34th annual meeting of the Society (No. 512) was held in the rooms of the Society, 1734-41 Monadnock Block, January 5, 1904. The customary annual banquet of the Society, to have been held on this evening, was dispensed with on account of the recent disaster at the Iroquois theater.

The meeting was called to order by President Modjeski at about 8:30 p. m., with about 65 members and guests present.

The Secretary read the Minutes of the regular meeting of December 2, and the extra meeting of December 16, 1903, which were approved.

The Secretary announced, on behalf of the Board of Direction, that at their meeting held January 2, 1904, the following applicants were elected to membership in the Society:

Arthur S. Robinson, Elkhart, Ind., Active.
Carl J. Rhodin, Thebes, Ill., Active.

Also that the following new applications had been received:

John P. H. Perry, Plano, Ill., Junior.
Isaac F. Stern, Chicago, Active.
John N. J. Hilbert, Chicago, Active.
Walter Scott Marston, St. Louis, Mo., Junior.
Benjamin E. Gage, Chicago, Junior.
Arthur B. Crozier, Chicago, Active.
Frank C. Kettler, Chicago, Junior.
Chas. W. Shepherd, Chicago, Junior.
Harvey H. Cosley, Chicago, Junior.
R. M. Hosea, Denver, Colo., Active.
James Harvey Sawyer, Chicago, Active.
Edward C. Slocumb, Chicago, Junior.
Walter F. Reichardt, Little Rock, Ark., Junior.

On motion of Mr. Finley, this report from the Board of Direction was accepted

The Secretary read the report of the Judges of the Election for officers of the W. S E. for 1904, as follows:

JANUARY 5, 1904.

To the Western Society of Engineers:

The undersigned Judges of Election, having canvassed the ballots cast for the officers of this Society for 1904, have the honor to report as follows:

Total number of ballots received	323
Total number of ballots rejected as irregular	9
Total number of ballots counted	314
Number of votes cast for President:	
H. W. Parkhurst	302
Number of votes cast for First Vice President:	
C. W. Hotchkiss	294
Number of votes cast for Second Vice President:	
W. L. Abbott	124
W. C. Armstrong	77
E. B. Ellicott	68
C. F. Foster	36
Number of votes cast for Third Vice President:	
W. D. Pence	162
A. N. Talbot	132
Number of votes cast for Treasurer:	
Andrews Allen	285

Number of votes cast for Trustee for three years:

T. W Snow	127
E. E. R. Tratman	73
A. Reichmann	66
E. R. Shnable	39

Respectfully submitted,

P. Jones,
Jesse Lowe,
G. P. Nichols,
Judges of Election.

The Secretary then announced that the officers of the W. S. E. for the year 1904 were as follows:

President—H. W. Parkhurst.
First Vice President—C. W. Hotchkiss.
Second Vice President—W. L. Abbott.
Third Vice President—W. D. Pence.
Treasurer—Andrews Allen.
Trustee for three years—T. W. Snow.

Mr. Modjeski presented the following address as Retiring President:

ADDRESS OF RETIRING PRESIDENT, MR. RALPH MODJESKI, JANUARY 5, 1904.

The reports of the past year of the Secretary and various committees will be published in the Journal. I will therefore mention in outline only the standing of our Society. We have now 704 members, a gain of 66 over last year. Our accounts show our total net resources to be $9,105 or a gain over last year of $687.02.

The Library has been increased by a number of donations and a large number of purchased text books. We were in great need of such text books and I am glad to say that this deficiency is now being corrected to a large extent. It would be of great assistance to the Library Committee if members failing to find a certain book in the Library would report the fact to the Secretary.

Two things are necessary to the success of an Engineering Society, a large number and high character of membership, and valuable publications through its Journal. It is only through individual efforts of the members that we may raise our standard to that of our National Societies. You are urged to contribute good papers, without sparing efforts just because this is not a National Society, and you are urged to induce good engineers to join.

It may not be out of place for me to say here that the Society's present good standing is largely due to the good work done during the past year by the standing committees and especially to the untiring efforts of our Secretary, Mr. Warder.

Generally the annual address of the President of a Society of Engineers is expected to say something about the engineering progress during the past year. I shall not attempt this as I am sure you have no desire to praise your own achievements, but I do wish to say a few words about what might be accomplished in the near future. We are a *local* society, a society which is proud of calling Chicago its headquarters, though we have members even as far as the Philippine Islands. Let us then turn to our own city of Chicago. Many are the improvements that the professional engineer is expected to bring about, the problems that he is expected to solve. I can only touch upon the few most important ones. Improvements of sanitary conditions are among the foremost. Much has been done in this line in Chicago, but much remains to be done. We need purer water, better drainage of streets, cleaner streets and alleys. This all takes time but should be accomplished in time.

Transportation lines have often been compared with the arteries of a living body, the freer the circulation the healthier the body. Much remains to be done in our city in this direction. It may not be long before we see a large underground system of railways in Chicago. And no doubt the Chicago River will soon be widened, deepened and improved in a manner to take care efficiently of its enormous commerce.

The city beautiful should not be forgotten. There is no reason why Chicago should not, in time, be one of the beautiful cities of the world. Like other improvements this will take time, but the professional engineer and architect must work together to that end. I shall not enumerate what the beautifying of the city should consist of. This is too great a task for one man and is one demanding careful deliberation.

Chicago must get rid of the smoke nuisance. So far its only hope seems to be in the exhausting of bituminous coal fields.

The last to mention, but by no means the least important, are the improvements having in view the safety of the public in theaters, halls and other buildings. Here again the architect and the engineer should work together to one common end. The problem is not such as to be solved satisfactorily by the architect alone, or by the civil engineer alone, or by the mechanical or electrical engineer alone. All must cooperate. I hope the members present will express their ideas on this subject which is now so vividly on our mind.

But before we take up the discussion, I have one more, and a very pleasant duty to perform, and that is to place this gavel into the hands of our president elect, Mr. Parkhurst.

At the conclusion of his address, Mr. Modjeski introduced the new President of the Society for 1904, Mr. Henry W. Parkhurst, who made the following remarks on taking the Chair:

"I thank you for the honor bestowed upon me, and trust that a year from this time we may show as good a result in the condition of the Society, its library, publications, etc., as of the past administration."

President Parkhurst then announced that the subject for discussion at this meeting was the recent disaster at the Iroquois theater, which had been of such a saddening and depressing character that the Board of Direction decided it was best to dispense with the annual dinner.

To open up the discussion the Secretary read a letter from Mr. T. T. Johnston, M. W. S. E., which is printed herewith:

CHICAGO, January 4th, 1904

Mr. J. H. Warder, Secretary Western Society of Engineers .

DEAR SIR—I regret my probable inability to be present at the meeting tomorrow evening when the recent horrible theater fire will be discussed.

Any resolutions in memory of the poor unfortunate people who lost their lives is highly proper, and cannot be drawn too strongly. Likewise any resolutions of condolence with the grieving friends of the lost are highly commendable; we should extend to them our deep and sincere sympathy. Any resolution expressing the sense of the Society in favor of framing and enforcing good laws would also seem to be justified.

It is my opinion, however, that any resolutions referring to the physical merits of, or to the responsibilities for the fire would be unwise at this time. The influence of this catrastrophe is being felt over the whole civilized world; and its lesson, which is one of the roughest teachings experience has given the world in recent times, is but slowly entering our comprehension. Our profession will be asked to aid in interpreting the lesson, and already some of our own members are being called upon to act in such capacity. Moreover the question at hand constitutes a complicated matter, and will require much study to properly measure its many sides. In view of these things it is my opinion that the Society will give evidence of more fully appreciating the gravity of the subject by a dignified silence as to the merits of it, at least until some time later, when all the facts may be at hand. Meantime extend every sympathy to the afflicted and console them in all ways that we can.

Respectfully submitted,

THOS. T. JOHNSTON.

Discussion followed from Messrs. Bley, Condron, Hatch, Finley, Randolph, Modjeski, Eldridge, Hopkins, W. H. Pearce, J. L. Hall, Andrews Allen, B. B. Carter and Parkhurst.

Mr. Bley made a motion that a committee of three members be appointed to draw up resolutions of sympathy for those who suffered loss in the recent Iroquois disaster, to be appointed by the Chair. This motion was carried, and the Chair appointed Messrs. Isham Randolph, Chairman, John Brunner and B. E. Grant on that committee.

Mr. Bley also moved that a committee of five members of the Society be appointed by the Chair to collect and preserve such evidence as it may find, and to report a summary of the evidence to the Society at some future date, recommending the best means of preventing a repetition of the disaster at the Iroquois Theater.

Mr. Pearce offered an amendment to this motion, suggesting that the number on the committee be made 20 instead of 5. Mr. Bley accepted this amendment with the exception of making the number 15 instead of 20.

The motion as amended was then put before the house and was lost.

Mr. Condron announced that the Society were the guests of the C., B. & Q. R. R. on a trip to Plano Ill., in November, and moved that the customary thanks of the Society be extended to the officials of that railroad for courtesies on that occasion. This motion was unanimously carried.

The meeting adjourned at 10:40 p. m.

ANNUAL REPORTS.

TREASURER'S REPORT FOR 1903.

To the Board of Direction, Western Society of Engineers, Chicago:

GENTLEMEN: I respectfully submit herewith a statement of the Treasurer's account for the year 1903, as follows:

CASH STATEMENT.

January 1st, 1903, Cash (including in $2,000 certificates of deposit)	$2,100.64
Investments	3000.00

RECEIPTS.

Dues	$5,464.00		
Entrance Fees	741.00		
Subscriptions	300.25		
Advertisements	2,432.28		
Journal Sales	209.44		
Interest	149.36		
Journal	19.85		
Library	67.25		
House Expense	264.05		
Stationery, postage and exchange	2.35		
General Printing	167.50		
Chanute fund	50 00	9,867.33	$14,967.97

EXPENDITURES.

Interest	28.75		
Journal	3,863.78		
Library	585.24		
House Expense	2,489.57		
Entertainment	152.00		
Stationery, postage and exchange	525.00		
General Printing	736.00		
Services	1,475.00		
Furniture and Fixtures	58 60		
Chanute fund	40.00	9,953.94	
Cash in Bank December 31, 1903		1,514.03	
Investments		3,500.00	$14,967.97

Respectfully,

(Signed) ANDREWS ALLEN,
Treasurer.

RECEIPTS, 1903.

Accounts	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Totals
Dues	$2,107.85	$755.00	$333.75	$645.10	$298.35	$174.55	$401.25	$193.70	$137.50	$142 10	$130.15	$144.70	$5,464.00
Entrance Fees	20.00	103.00	24.00	127.00	77.00	76.00	30.00	56.00	40.00	39.00	46.00	103.00	741.00
Subscriptions	143.75	55.00	18.50	26.50	8.00	4.00	2.00	2.00	4.00	14 00	2.00	20.50	300.25
Advertisements	78.50	30.00	18.00	80.64	584.50	231.00	191.50	40 50	37.50	560.64	385.05	194 00	2,432.28
Sales—Journal	14.40	77.40	19.70	14.00	4.75	7.60	6.65	24.49	.75	5.60	24.10	10 00	209.44
Interest	49.56		10.09	1.64		1.37	26.15	39.50	9.80	11.25			149.36
Investments									500.00	500.00			1,000.00
Medal Fund	25.00						25.00						50.00
Journal Account	1.25				5.85				9 75			3.00	19.85
Library Account		11.50	10.15	6.85		6.30		11 35	1.75	12.10	7.25		67 25
House Expenses		73.10	39.50	83.20	15.00	12.00		5.00	2.25			34 00	264.05
Stationery, Postage and Exchange				.35					2.00				2 35
General Printing						43.00	10.00	67.00	25.00		20.00	2.50	167.50
Cash Totals	$2,440.31	$1,105.00	$473.69	$985.28	$993.45	$555 82	$692.55	$439.54	$770.30	$1,284.69	$615.00	$511.70	$10,867.33

Cash Balance on Hand, January 1, 1903 .... 2,100.64

$12,967.97

EXPENDITURES, 1903.

Accounts	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Totals
Interest				$ 28.75									$ 28.75
Investments				1,500.00									1,500.00
Medal Account									$ 40.00				40.00
Journal Account	$137.87	$612.58	$112.65	489.09	$488.89	$112.83	$153.96	$120.52	505.78	$532.28	$146.18	$451.15	3,863.78
Library	14.50	88.19	54.63	57.42	36.43	59.56	49.15	32.81	128.58	37.28	18.03	8.66	585.24
House Expenses	232.79	175.40	220.75	184 11	172.63	221.01	280.27	253.15	165 42	232.03	165.92	186.09	2.489 57
Stationery, Postage and Exchange	43.30	46.86	36.15	66.61	51.05	51.15	19.96	24.40	73.83	23.77	45.00	42 92	525 00
General Printing	88.20	79.45	19.45	79.65	103.35	26.35	6.20		185.55	27.75	58.90	61.15	736 00
Secretary's Salary	100.00	125.00	125.00	125.00	125 00	125.00	125.00	125.00	125.00	125.00	125.00	125.00	1,475.00
Entertainment Account					152.00								152.00
Furniture and Fixtures			12.00		6.25	14.25	4.10	15.00	7.00				58.60
Cash Totals	$616.66	$1,127.48	$580.63	$2,530.63	$1,135.60	$610.15	$638.64	$570.88	$1,231.16	$978.11	$559.03	$874.97	$11,453.94

Cash Balance on Hand December 31, 1903 ...... 1,514.03

$12,967.97

REPORT OF FINANCE COMMITTEE.

CHICAGO, January 5, 1904.

To the Board of Direction, Western Society of Engineers, Chicago:

GENTLEMEN: The Finance Committee respectfully submits the following conservative estimate of the financial condition of the Western Society of Engineers December 31, 1903:

RESOURCES.

Cash on hand subject to check		$1,504.03	
Cash in hands of Secretary		50.00	
Cash in transit from Entertainment Committee		152.00	
		1,706.03	
Dues for 1903	$260.00		
Subscriptions to Journal	30.00		
Advertising in Journal	462.00		
Journal sales	5.90		
Rent	15.00		
Journal account, cuts sold	6.60	779.50	
Investments	$3,500.00		
Furniture and Fixtures' Account	706.00		
Stock of Journals (estimated)	700.00		
Books in Library (estimated)	3,500.00	8,406.00	$10,891.53

LIABILITIES.

Bills payable, vouchers for December bills	685.92		
Advance payments received for:			
Dues	46.45		
Subscriptions to Journal	19.16	751.53	
Chanute Medal Fund		1,035.00	
Net resources		9,105.00	$10,891.53

(Signed) Finance Committee,
H. W. PARKHURST,
ANDREWS ALLEN,
GEO. A. DAMON.

SECRETARY'S REPORT.

JANUARY 2, 1904.

To the Board of Direction, Western Society of Engineers, Chicago:

GENTLEMEN:—The growth of membership in the Society for the past year has been healthy and steady, though not remarkable in numbers. A table presented herewith shows the gains and losses in the membership. The net increase for the year is 66, and the total membership to December 31, 1903, is 704.

There have been seven deaths among our numbers, as follows:—of which Mr. Barrington was not known at the time of the annual report a year ago:

H. E. Stannard, Member, January 4, 1903.
Carl Binder, Member, February 4, 1903.
H. C. Draper, Member, May 23, 1903,
G. S. Morison, Member, July 1, 1903.
William A. Bruce, Junior, July 25, 1903.
Edward Barrington, Member, October 3, 1902.
James P. Mallette, Member, October 22, 1903.

The membership has also been decreased by resignations and those dropped for cause by eleven (11). All as indicated in the table herewith.

CLASS.	1902.			1903.			GAINS.		LOSSES.		
	Resident.	Non-Resident	Total.	Resident	Non-Resident.	Total.	Elected.	Transferred.	Transferred	Deaths.	Dropped and Resigned.
Honorary	1	.	1	1	....	1	...	..	....	...	
Active	314	214	528	336	244	580	56	8	...	6	6
Associate	34	5	39	43	7	50	13	....	1	...	1
Juniors	37	33	70	49	24	73	15	...	7	1	4
Totals	386	252	638	429	275	704	84	8	8	7	11

There have been 25 called meetings during the year 1903, including the Annual Meeting, two "Ladies' Nights," one Smoker with informal address, and a joint meeting with the American Institute of Electrical Engineers.

The list is as follows:

Tuesday, January 6, 1903:
The 33d Annual Meeting (No. 487), at Victoria Hotel, with report of election of officers for 1903. Dinner and Adresses.

Wednesday, January 15, 1903:
Extra meeting (No. 488), Mr. G. N. Linday, M. W. S. E., read a paper on "Some Curious Kinds of Lattice Trusses."

Mr. T. L. Condron, M. W. S. E., presented his paper on "Specifications for Material and Workmanship for Steel Structures."

Wednesday, February 4, 1903:
Regular meeting (No. 489), Mr. V. R. Lansingh addressed the Society on "Engineering of Illumination."

Wednesday, February 18, 1903:
Extra meeting and Smoker (No. 490), Mr. Wiederhold, of Philadelphia, gave an informal address on Asphalt and Bitumen, and the use of the same for floors, roofs, etc.

Wednesday, March 4, 1903:
Regular meeting (No. 491), Mr. W. B. Jackson, M. W. S. E., presented his paper on "Hydraulic Developments as related to Electrical Installation."

Wednesday, March 18, 1903:
Extra meeting (No. 492), Mr. E. Gonzenbach, M. W. S. E., presented his paper on "The Third Rail for High Speed Electric Service."

Tuesday, March 24, 1903:
Extra meeting (No. 493), held jointly with the Chicago Branch of the American Institute of Electrical Engineers in Fullerton Hall, when Mr. B. J. Arnold, M. W. S. E., addressed the company on "The Chicago Transportation Problem."

Wednesday, April 1, 1903:
Regular meeting (No. 494), Prof. Chas. S. Slichter, M. W. S. E., addressed the Society on "The Measurement of Underflow Streams in Southern California."

Wednesday, April 15, 1903:
Extra meeting (No. 495), Mr. Richard McCulloch, M. W. S. E., read his paper, "Notes on European Tramways."

Wednesday, April 29, 1903.
Extra meeting (No. 496), Mr. Robert C. Smith, M. W. S. E., read his paper on "Borings for the Bohio Dam, Pamama."

Saturday, May 2, 1903:
Extra meeting (No. 497), called by the Entertainment Committee for a "Ladies' Night," was held in Kimball Hall. Prof. E. E. Sparks gave an illustrated lecture on "The Beginnings of Chicago."

Wednesday, May 6, 1903:
Regular meeting (No. 498), Mr. H. J. Slifer, M. W. S. E., presented his paper on "Maintenance of Way."

Wednesday, May 20, 1903:
Extra meeting (No. 499), Mr. W. W. Curtis read a paper on "Timber Treating Plants."

Wednesday, June 3, 1903:
Regular meeting (No. 500), Mr. Willard Beahan, M W. S. E., presented his paper on "Railroad Reconnaissance." The paper by Mr. W. C. Bunnel, Junior M. W. S. E., on "Topographical Surveying," was presented by title.

Wednesday, June 24, 1903:
Extra meeting (No. 501), Mr. Wilbur Wright, of Dayton, Ohio, addressed the Society on "Experiments and Observations on Soaring Flight."

Wednesday, September 2, 1903:
Regular meeting No. 502), the paper by Mr. L. B. Merriam, M. W. S. E., on "The Development of a new Coal Field in Colorado," was read by the Secretary.

Wednesday, September 16, 1903:
Extra meeting (No. 503), Mr. G. H. Kimball, of New York, presented a paper on "The Tie Problem; with Special Reference to Concrete Ties."

Wednesday, September 30, 1903:
Extra meeting (No. 504), Mr. T. T. Johnston, M. W. S. E., read his paper on "Hydro-electric Power Development at Joliet, Ill."

Wednesday, October 7, 1903:
Regular meeting (No. 505), Prof. A. Marston, M. W. S. E., read his paper on "Sewage Disposal in Iowa."

Saturday, October 17, 1903:
Called meeting (No. 506), "Ladies' Night." Mr. W. J. Karner, M. W. S. E,. gave an illustrated lecture, "Across the North Sea to Holland."

Wednesday, October 31, 1903:
Extra meeting (No. 507), Mr. G. A. M. Liljencrantz, M. W. S. E., read his paper on "The Haskell Self-Registering Water Gauge."
Discussion on Mr. T. T. Johnston's paper, "The Hydro-Electric Power Development at Joliet," was presented by Messrs. Randolph, Wisner, Benezette Williams, and others.

Wednesday, November 4, 19 3:
Regular meeting (No. 508), Prof. Storm Bull, M. W. S. E., read his paper on "The Use of Superheated Steam."

Wednesday, November 18, 1903:
Extra meeting (No. 509), Mr. G. F. Culmer read his paper on "Asphalt and Allied Hydro-Carbons."

Wednesday, December 2, 1903:
Regular meeting No. 510), Mr. A. J. Mason, M. W. S. E., addressed the Society on "The Movement of Iron Ore on the Great Lakes."

Wednesday, December 16, 1903:

Extra meeting (No. 511), Mr. W. H. Pearce, M. W. S. E., read his paper on "Heating from a Central Station."

Of these several papers and addresses, eighteen (18) have been printed in the JOURNAL during the past year.

J. H. WARDER, Secretary.

LIBRARIAN'S REPORT.

JANUARY 2, 1904.

To the Library Committee of the Western Society of Engineers, Chicago:

GENTLEMEN:—The following report of the Library of the Western Society of Engineers is respectfully submitted:

Total number of books accessioned to December 31, 1903		4,766
Total number of books accessioned to December 31, 1902		4,297
Books added to Library during 1903,		469
Of these, there were purchased at a cost of $234.01	93	
Gifts from various sources	205	
Exchanges, many bound by W. S. E.	171	469

The Society has also received between 400 and 500 pamphlets on various subjects, many of which have been filed in the Library.

There has been no notable change in the exchange list, which remains about as last year, numbering about 200.

The rooms of the Society were all thoroughly cleaned and the walls were freshly calcimined during the midsummer vacation, the books being all taken off the shelves and wiped off.

A change was made in ceiling lights in the Reading Room and Secretary's Office. Some additional shelving was put up in the Library, and additional bookcases were put in the Reading Room.

These improvements cost about $58.60, and are charged to "Furniture and Fixtures Account."

The total charge against the Library for 1903 is $585.24, divided as follows:

Books, including binding.	$324.22	
Services	181.56	
Sundries.	79.46	585 24

Very respectfully submitted,

J. H. WARDER, Librarian.

ABSTRACT OF MINUTES OF THE SOCIETY.

EXTRA MEETING, January 20, 1904.

An extra meeting of the Society (No. 513) was held in the rooms of the Society, January 20, 1904.

The meeting was called to order at about 8.30 p. m. with President Parkhurst in the Chair and about 85 members and guests present.

Mr. Oscar Sanne, M. W. S. E., presented his paper on "Graphical Calculation of Flange Stresses in Girders and Trusses," which was illustrated by lantern slides.

Mr. Joseph L. Ferrell, of Philadelphia, then presented his paper on "The Preservation of Wood from Fire and Decay." This paper was illustrated with a number of experiments, showing the resistance of treated wood against fire.

The paper was discussed by Messrs. Wm. Sooy Smith, B. B. Carter, Finley, Layfield, Lowe, and Ferrell.

The meeting adjurned about 10.30 p. m.

REGULAR MEETING, February 3, 1904.

A regular meeting of the Society (No. 514), was held in its rooms in the Monadnock Block, February 3d, 1904. The meeting was called to order at 8:20 p. m. with President Parkhurst in the Chair and about 65 members and guests present.

The Secretary read an extract from the Minutes of the annual meeting held January 5th, and also the Minutes of the extra meeting of January 20th, which were accepted.

The Secretary announced that at a meeting of the Board of Direction held February 2d, the following list of applicants were elected into membership in the W. S. E.:

Joseph E. Bond, Chicago, Associate.
Perry L. Hedrick, Chicago, Active.
Stephen A. Wallace, Chicago, Junior.
John P. H. Perry, Plano, Ill., Junior.
Isaac F. Stern, Chicago, Active.
Walter S. Marston, St, Louis, Mo., Junior.
Benj. E. Gage, Chicago, Junior.
Frank C. Kettler, Chicago, Junior.
Chas. W. Shepherd, Chicago, Junior.
Harvey H. Cosley, Chicago, Junior.
Raphael M. Hosea, Denver, Colo., Active.
Edward C. Slocumb, Chicago, Junior.
Walter F. Reichardt, Little Rock, Ark., Junior.

Also that the following list of new applications had been received:

Fred. L. Hartigan, Chicago, Active.
Harry M. Trippe, Chicago, Active.
George Loughnane, Mason City, Iowa, Active.
Harry H. Ross, Cleveland, Ohio, from Junior to Active.
Carl Weber, Chicago, Active.
Oscar J. West, Chicago, Active.
Emmons Collins, Chicago, Active.
Wm. J. Vanderkloot, Chicago Junior,
M. A. Vanderkloot, Chicago, Associate.
Harry B. Merriam, Dubuque, Iowa, Active.
Edward A. Renwick, Chicago, Active.
Fred. Norlin, Chicago, Active.
W. H. Converse, Chicago, Active.
Curtis C. Saner, Chicago, Junior.

The Secretary announced the death of Mr. Charles E. Ferreira, an active member of the Society, which occured on January 25, 1904, and suggested that a committee be appointed to prepare a Memorial of this deceased member, as well as for Mr. J. P. Mallette, whose death was announced some time ago.

Mr. Isham Randolph moved that the Chair appoint committees to prepare Memorials of the two members mentioned. The motion was carried.

The Secretary announced that Mr. Liljencrantz, Chairman of the Entertainment Committee, would like to meet in an informal way as many of the members as were interested and could find it convenient to come, in the Society rooms next Saturday afternoon, February 6th, for the purpose of discussing entertainments for the current year.

The following Memorial, prepared by Messrs. Isham Randolph, John Brunner and B. E. Grant,—the committee appointed by the President W. S. E. at the annual meeting of the Society held January 5, 1904, to draw up resolutions of sympathy for those who suffered loss in the Iroquois disaster—was read by the Secretary:

JANUARY 12, 1904.

WHEREAS: On Wednesday, December 30, 1903, a calamity visited Chicago, more appalling even than the besom of destruction which swept the City in 1871 more appalling because in the midst of a holiday season, when hearts were attuned to mirth, when the joy of living was being accentuated, death in its most horrid guise fell upon hundreds of innocent merry-makers, and swept to one common doom young men and maidens, honored and honorable age, and loved and lovely infancy. The pen of history has seldom been dipped in darker hues of woe than those which record the tragedy of the Iroquois Theatre. When the glare of those flames was quenched, the light of nearly 600 lives had gone out; a city was in tears, a land in mourning, and a sphere thrilled with the "touch of nature which makes the whole world kin." All of this being so, it is fitting that an organization of the world's workers, such as we are, should place upon our records some expression of the feeling of our members born of this great calamity.

Therefore, be it resolved that we, the officers and members of the Western Society of Engineers, extend to all of those stricken and bereaved by this horrid disaster our profound sympathy, and that we invoke for their consolation every aid that friendship can suggest, or a merciful providence vouchsafe.

And further, inasmuch as this sorrow has touched this Society through members who have been called to mourn their loved ones lost, be it resolved that we do hereby extend to those of our members who have thus suffered our especial and fraternal sympathy.

On motion of Mr. Fred. Hill this resolution was unanimously adopted and ordered spread upon the Minutes of the Society; copies to be transmitted to the papers.

As there was no further business to come before the Society, Prof. Edmund Bulkley was introduced, who addressed the meeting on "The Eastern Question—the Russian and the Japanese." This address was supplemented with many pleasing lantern slide views.

Prof. F. B. Badt next addressed the Society, and was followed by the English vice-consul. Further discussion of the Eastern Question was offered by Messrs. Gould, Seafert, and Prof. Chô-Yô.

The meeting adjurned at 10:50 p. m.

EXTRA MEETING, February 17, 1904.

An extra meeting of the Society (No. 515) was held in the Society rooms, Wednesday, February 17, 1904. In the absence from the city of President Parkhurst and First Vice-President Hotchkiss, the meeting was called to order by Second Vice President Abbott, at 8:30 p. m., with about 40 members and guests present.

Mr. A. Bement, M. W. S. E., presented his paper on "Some Performance of Boilers and Chain Grate Stokers, with Suggestions for Improvements." The Secretary presented a written discussion from Mr. C. H. Hurd, M. W. S. E., of Indianapolis. Further discussion was offered by Messrs. W. L. Abbott, Junkersfeld, Chamberlain, Scott, Bond, J. P. Johnston, W. L. Goddard, Bley, Vial and Mayer. Mr. Bement closed the discussion and the meeting adjourned about 10:15 p. m.

J. H. WARDER, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for December, 1903, we have the pleasure to report the following additions to the library and gifts from donors named :

BOOKS PURCHASED.

Alternating Current Phenomena—Theory and Calculation, 1900. By Chas. P. Steinmetz.

American Municipal Progress, 1902. By Chas. Zueblin.

Architectural Engineering, with special reference to high building construction, including many samples of permanent office buildings. By J. K. Freitag, 1901.

Architects' and Builders' Handbook, 1903. By Chas. R. Adams.

Building Construction and Superintendence, Vol. 1—Masons' Work, 1896. Vol. 2—Carpenters' Work, 1898. By F. E. Kidder.

Centrifugal Pump, Turbines and Water Motors, including the theory and practice of hydraulics; specially adapted for engineers. By Charles H. Innes, 1901.

Docks and Dock Construction. By C. Colson, 1894. (Longman's Civil Engineering Series.)

Civil Engineering, a Treatise on. By W. M. Patton, 1895.

Electric Railway Economics and Preliminary Engineering. By W. C. Gotshall, 1903.

Electrical Engineers' Pocket Book. A Handbook of Useful Data for Electricians and Electrical Engineers. By Horatio A. Foster, 1901.

Engineering for Land Drainage. A Manual for Laying Out and Constructing Drains for the Improvement of Agricultural Lands, 1903. By Chas. G. Elliott.

Fireproofing of Steel Buildings. By J. K. Freitag, 1899.

High Office Buildings, planning and construction. By W. H. Birkmire, 1898.

Irrigation and Drainage. Principles and Practice of their Cultural Phases, 1903. By F. H. King.

Irrigation Institutions, 1903. By Elwood Mead.

Lubrication and Lubricants A Treatise on the Theory and Practice of Lubrication, and on the Nature, Properties, and Testing of Lubricants. By Archbutt and Deeley, 1899.

Mineral Oils and their By-products. A short history of the Scotch shale oil industry; the geological and geographical distribution of Scotch shales, recovery of acid and soda used in oil refining, and a list of patents relating to apparatus and processes for obtaining and refining mineral oils. By I. I. Redwood, 1897.

Municipal Engineering and Sanitation. By M. N. Baker, 1901.

Petroleum, Technology of. The Oil Fields of the World; their history, geography and geology. Annual production, prospection and development. Oil Well Drilling, Explosives and the use of the "Torpedo." Transport of Petroleum by Sea and by Land. The Storage of Petroleum, Technical Data and Tables, Formulae, Problems, etc., etc., 1901. By Neuberger & Noalhat

Power Plants, Mechanical Engineering of. By F. R. Hutton, 1897.

Resident Engineers, A Manual for. Containing general information on construction. By Molitor & Beard, 1903.

Roads and Pavements in France. By A. P. Rockwell, 1895.

Roof Trusses, Design of Simple. With an introduction to the elements of graphic statics. By Malverd A. Howe, 1902.

Steam Power and Millwork. Principles and modern practice. By George Wm. Sutcliffe, 1894.

Structural Mechanics. Comprising the strength and resistance of materials and elements of structural design, with examples and problems. By Charles E. Greene, 1897.

Wire, Its Manufacture and Uses. Embracing comprehensive descriptions of the construction and applications of wire ropes. By J. Bucknall Smith, 1891.

MISCELLANEOUS GIFTS.

Adams, B. B., Sec'y, Railway Signalling Club, Proceedings for 1901-2-3.

Atkinson, Edward, Insurance Engineering Experiment Station pamphlets:
"The Protection of Steel from Corrosion."
"Bog Fuel, Coke, Gas, and the Secondary Products of Gas." 1903.

Bates, W. S., M. W. S. E. "Ephemeris and Nautical Almanac for 1903." Cloth.

Gozenbach, Ernest, M. W. S. E., "Engineering Preliminaries for anInterurban Electric Railway." One cloth bound volume.

Gurley, W. and L. E. "Gurley's Manual of American Engineers and Surveyors Instruments." Cloth bound volume.

Schoenenberger & Son, Chicago, seven bound volumes:
"Introduction, a la Science de L'Ingenieur," by Claudel. Vols. 1-2
"La Rogue Pratique de L'Art de Construire," by Claudel.
"Formulas, Tables et Renseignements Usueles," " Vols. 1-2
"Traite, Special de Coupe des Pierres." Text and Atlas. By Douliot.

Tratman, E. E. R., M. W. S. E., Proceedings Railway Signalling Association for 1903. Pamphlet.
Proceedings, American Water Works Association for 1903. Pam.
"Eucalypts Cultivated in the United States." McClatchie.
"American Society of Municipal Improvements," 9th annual convention. 3 pamphlets.

Warder, J. H. "The Metric System." By Davis. Cloth bound volume.

City of Chicago, Mayor's Message; 27th Annual Report, Department of Public Works, 1902.

Commercial Museum, The World's Commerce and American Industries. Pam.

Engineer Publishing Co., copy of "The Engineer" for April 15, 1902.
"Boilers, Furnaces and Feed Water Heaters" Pam.

New York Railroad Club, Vols. XI and XII, Proceedings for 1900-1901. Cloth bound volumes.

American Association for the Advancement of Science; preliminary announcement of the Fifty-first Annual Meeting, 1902. Pamphlet.

Massachusetts Institute of Technology, Decennial Catalogue, 1903. Pamphlet.

Michigan State Board of Agriculture, 42d annual report of secretary; 16th annual report of Experiment Station.

Worcester Polytechnic Institute, 34th annual calendar, 1903-1904.

World's Fair Bulletins, St. Louis, Dec. 1903, Jan. and Feb. 1904.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey, Department of Interior. Pamphlets:
Production of Gas, Coke, etc., in 1902. Parker.
" " Monozite in 1902. Pratt.
" " Cement in 1902. Kimball.
" " Gypsum in 1902. Adams.
" " Mineral Waters in 1902.
" " Zinc in 1902. Kirchhoff.
Report of Progress of Stream Measurement in 1902. Newell.

Trade Catalogue No. 1018. "Mine and Ore Cars."
Statistics of clay working industries in the United States in 1902.
U. S. Department of Agriculture. Pamphlet:
Report of the Forester for 1903. Pinchot.
Bureau of Labor, Dep't. of Commerce and Labor, January, 1904. Pamphlet.
Department of Interior, Census office, 12th Census of United States in 1900. Special Reports Employees and Wages. Cloth bound volume.
Department of Interior, Commissioner of Education,
Annual Reports of Department of Interior, 1902.

EXCHANGES.

American Institute of Mining Engineers, List of Officers, Members, Rules, etc., dated November, 1903. Pamphlet.
American Society of Mechanical Engineers, Transactions for 1903. Volume XXIV. Pamphlet.
Boston Transit Commission, Eighth Annual Report, 1901-1902.
Connecticut State Railroad Commissioners, (Wm. O. Seymour), 51st Annual Report, 1903.
Institution of Naval Architects, London, four bound volumes, Indices Vol. I to XLII inclusive.
Institution of Engineers and Shipbuilders of Scotland, Vol. XLVI, Transactions, 1902-1903. Cloth bound.
New England Cotton Manufacturer's Association, Transactions Semi-annual Meeting, September-October, 1903. Bound volume.
Tonindustrie Zeitung, Kalendar, 1904. 2 volumes.
University of Montana, (M. J. Elrod) Lectures at Flathead Lake. Pam.
Royal Society of New South Wales, Sidney, Australia, Journal and Proceedings, 1876-1902, inclusive. 16 bound and 9 unbound volumes.

TRADE CATALOGUES.

Atlas Car and Manufacturing Co., Cleveland, Ohio. Pamphlet.
Chicago Pneumatic Tool Co., Reprint of Decision of Court, Eastern District, Pa. Infringement of Patents.
Fairbanks, Morse & Co., Chicago. Hoists and Mining Machinery.
Hoshor-Platt Company, New York. Industrial Railways.
Park Manufacturing Co., Chicago. Park Automatic Loader.
Power and Mining Machinery Co., New York. Gas Plants for Power Manufacturing and Metallurgical Work. Gas for Furnace Work Gas Power Plants for Mining and Smelting.
Robb-Mumford Boiler Co., New York. Robb-Mumford Boilers.
Stewart Washer Co., Birmingham, Ala. Catalogue No. 2 of Coal Washer.

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each applicaton, identified by number only, and stating character of position sought and salary expected, will be published in the Journal. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

By Order of the Board of Direction.

J H. Warder, Secretary.

August 5, 1902.

WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND MEETING ROOMS
1734-41 Monadnock Block, Chicago

LIST OF OFFICERS FOR 1904

President	H. W. PARKHURST
First Vice-President	C. W. HOTCHKISS
Second Vice-President	W. L. ABBOTT
Third Vice-President	PROF. W. D. PENCE
Treasurer	ANDREWS ALLEN

TRUSTEES

J. W. ALVORD	Term expires January, 1905
B. E. GRANT	Term expires January, 1906
T. W. SNOW	Term expires January, 1907
O. CHANUTE, W. H. FINLEY, R. MODJESKI	Past Presidents.

The above named officers of the Society and three past presidents, constitute its Board of Direction

Secretary and Librarian
J. H. WARDER

COMMITTEES

On Finance—C. W. Hotchkiss, Andrews Allen, C. F. Loweth.

On Publication—W. L. Abbott, E. E. R. Tratman, John Brunner.

On Membership—W. H. Finley, W. H. Baldwin, Geo. A. Damon.

On Library—B. E. Grant, J. W. Alvord, A. Reichmann.

On Entertainment—G. A. M Liljenkrantz, W. J. Karner, J. G. Bergquist, A. R. Eldridge, W. C. Armstrong.

MEETINGS

Regular Meeting—1st Wednesday evening of each month except January, July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

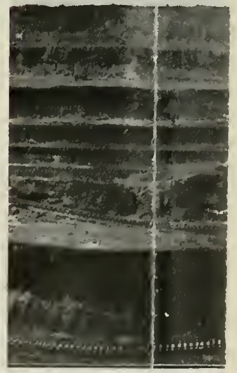
Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the JOURNAL.

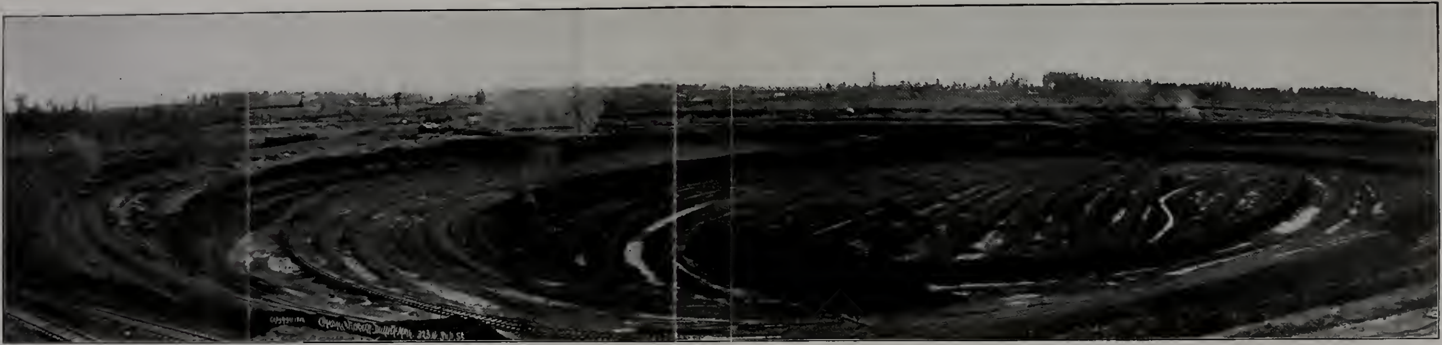
IRON ORE ON TH

MAHONING MINE, MINN.

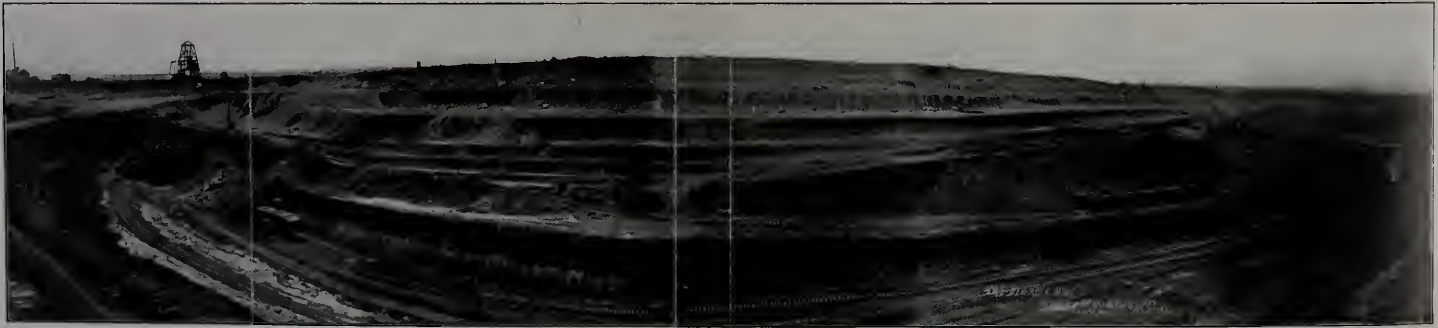


BIWABIK MINE, MINN.

excavating of soft ore



MAHONING MINE, MINN. MISSABE REGION.



BIWABIK MINE, MINN. MISSABE REGION.

These views show the excavating of soft ore, in open workings, with steam shovels.

Journal of the

Western Society of Engineers.

VOL. IX. APRIL, 1904. NO. 2.

THE MOVEMENT OF IRON ORE ON THE GREAT LAKES.

Arthur J. Mason, M. W. S. E.

Presented December 2, 1903.

We should feel gratified, I think, at the realization that finally engineers are to have an inning. For many years our profession has been regarded as a sort of poor relation of the other professions; but good work always finally counts, and it seems to me that the world is beginning to appreciate the supreme importance of the engineer to society.

A year or two ago, Mr. Choate, the Ambassador to England, was invited to address the American Society of Engineers when their new building was opened. Mr. Choate states that, having the evening in mind, he sat down in his library to find out what engineers really were; in short, to get the material for his speech! As he read "Smiles' Lives of the British Engineers," he said he was awakened to a consciousness of the extraordinary service of engineers to mankind; that so much of everything which we have to be grateful for, as distinguishing the present time from the past, we may thank the engineer for; that all the other professions have prospered as adjuncts of the great works and benefits brought about by the mind of the engineer.

A friend of mine lately in a conversation with Mr. Edison remarked that he believed that 90 per cent of the improvements in the world, within the last century, had been brought about by engineers; to which Mr. Edison replied, "Who in the world furnished the other 10 per cent."

I think if we will examine closely into this matter we will find that to the use of iron and steel the engineer must attribute his power to bring about these great changes. Not only is the material itself so ideally adapted for its varied uses, but its very nature has stimulated the engineer, introduced methods of precision which have broadened and educated him.

I will ask you now to try and realize what this Society would be if timber was used in Chicago as it was twenty years ago.

I remember when I was much younger and living in a foreign country, that I associated America with forms of temporary construction; the general use of timber and cast iron.

Those of us who have for the last twenty years watched the scientific papers must be conscious of the steady change which has taken place. To-day the American press illustrations and articles are typical of the most permanent and substantial construction—a change which is singularly true of Chicago.

Before the fire this city was celebrated for its temporary character. It has since shown to the world the best method of building large, substantial and permanent buildings.

It is not my intention to-night to do more than call your attention to the vast effort required each year to produce the raw material to be made into steel, to lay before you the outline of this great operation, and, if I can, to point out whether the engineer may step in and do further good. It is a curious fact that the very land which furnished the timber now furnishes the ore to make steel to take the place of that timber.

We have lately been greatly interested in discussing the proposed Panama Canal and have been astonished at the magnitude of the work involved. It will probably give respect to the matter about which I am now speaking if I tell you that the annual effort to produce the necessary iron ore on the Great Lakes involves as much excavation in one year as the execution of the great cut on the Panama Canal. All of this material must be taken out of its native place and transported more than a thousand miles to the furnaces.

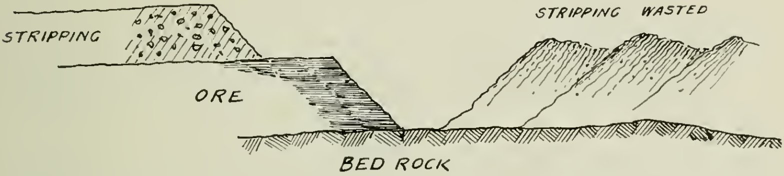
We have every reason to suppose that great as this annual effort is, it is but a beginning. The use of iron is getting to be so general, we find that it is in the out-of-the-way homely things that much metal goes; for instance, I feel sure that it must be a great surprise to those present to learn that the total amount of steel used per annum in structural shapes, in all the viaducts and all the machines is a smaller tonnage than that made into wire, for the manifold uses wire is put to. I find that the production of iron and steel rods is a little more than 1,574,000 tons; whereas as the total tonnage for structural shape is but 1,300,000 tons. Nothing is more certain, it seems to me, than the more and more extended use of steel, not only for the purposes which we are now accustomed to see it used, but in endless other directions; just as we have seen the wooden freight car, the wooden lath and much else supplanted by steel, etc. Will it be many years before the street cars are of steel?

This is to impress upon you the possibilities.

I will not attempt a technical description of the iron ore producing region; you are generally aware that south of Lake Superior, at a distance from the lake averaging, we will say, 75 miles, a large amount of ore has been mined for many years; in 1902 aggregating 13,000,000 tons. To the northwest of Lake Superior, about the same distance from the lake itself, at Duluth, lies the great

Missabe region, which furnished in 1902 a like amount of ore; the two aggregating 27,000,000 tons. Ore from the south of Lake Superior is generally known as "Old Range ore," it is often hard, like rock, and is wholly mined under ground. The ore body on the northwest of Lake Superior is of soft ore and a large proportion of it is stripped and excavated with steam shovels.

The pictures on the screen describe typical mines in the Missabe region. It is felt in this Missabe region generally, that before very long, all ore will be stripped and mined with steam shovels even where one hundred feet of stripping must be removed. In this diretcion, it seems to me, opportunities are offered the engineer. The stripping is now removed in the familiar manner with steam shovels, delivered to dump cars and hauled off to some barren low ground. It is quite common to strip a great many acres at a time in this manner up to 40 feet to 50 feet deep. It seems to me that the possibilities of imitating the quarrymen in these mines are great; that is to say, stripping a certain portion of the ore, removing it and then using the hole to dispose of further stripping, in this manner.



Many of you must be aware of the beneficial effect of such a system of excavation on the drainage canal, relieving the shovel of the delays incident to the transportation of the material to a distance in cars. There is no doubt in my mind that a steam shovel, operating under such conditions, will do double as much work as it will if delivering to dump cars and material taken away in trains. All of the material, both stripping and ore, must be loosened by powder; it is not difficult to pierce or drill, black powder is used and, as near as I can get at it, the stripping requires about one-third of a pound of powder for each cubic yard; the ore probably takes twice as much powder to loosen. The cost of delivering ore to the car, including its proportion for the cost of stripping, runs, in round figures, 40c per ton; in underground mining, in the same region, the cost is probably doubly as great. Underground mining has, of course, an advantage in winter; it has been the practice to conduct underground mining all the year and create great stock piles in the vicinity of the shaft, which are transferred to railway cars in the spring. Where the ore is handled by a steam shovel, it is loaded direct into the railroad cars for transportation to Lake Superior.

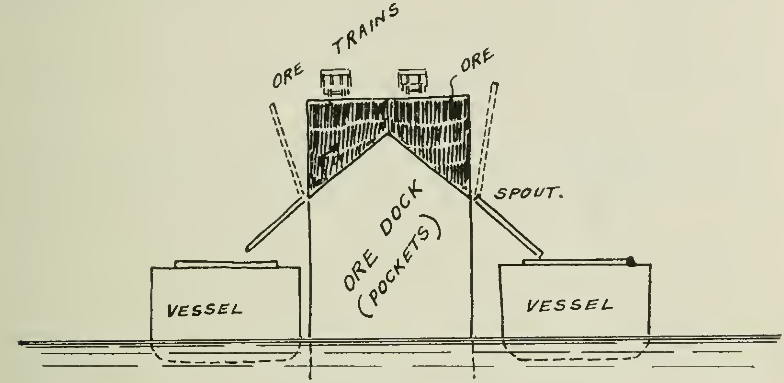
I have here a geological map of the Missabe district, and you will notice the ore body spreads out a distance of one hundred miles east and west; the deposit runs a mile or so in width, and curiously occupies a position just southward of a range of primary rock, just as though it had been intercepted in moving northward by this ridge. The Missabe, it seems, is another case of the geologist trying to make one district fit the peculiarities of another; for I understand from the old-timers on the ground that all those men familiar with the mines in Michigan declared the Missabe district would never amount to anything, and the record is full of surprises.

The first great mine was the Iron Mountain, a picture of which I have shown. I heard from the man who opened this mine that the original Merritt prospecting party insisted on looking for the ore where it ought to be found—according to their view. An old miner in the party wished to try, as he said, "down below," but the chiefs objected. After much disappointment the chiefs left the region, leaving instructions with the old Cornishman to complete a certain hole, and if it proved barren, to abandon the neighborhood. As soon as the leaders of the party were sufficiently far enough away, he followed his own views, putting a hole down in the lower ground, and found ore in a few feet; found, indeed, this Iron Mountain mine, which has produced something like 8,500,000 tons. Rather a valuable 80 acres. One could easily talk about these mines for the rest of the evening, and I shall be glad, later on, to make clear, if I can, anything that may occur to your minds. For the present we will take it for granted that we have our 27,000,000 tons loaded on railroad cars for transporting to the lake, making a million cars; 5,000 a day for the shipping season—thirty miles of cars. It is up to our railroad friends now to get this down to the vessel's side.

Now there are something like a hundred and fifty producing mines, and, until the United States Steel Corporation took hold, almost as many different kinds of ore, having presumably different characteristics and requiring to be kept separate, each from the other; unlike, you will realize, grain or corn, in this respect. Often the ore from the same mine is graded in several grades, according to its characteristics, chiefly as Bessemer and non-Bessemer ore. Now, this ore must be kept separate at each stage on its way to the furnace.

The chemist is actively at work all through the excavation season, and as fast as a car is loaded samples are taken, analyses of the ore made and its character determined before it starts on its journey to the lake.

The peculiarities of the handling of ore just mentioned have brought into requisition the ore pockets of the upper lakes. All ore is now handled through these pockets. They consist of a timber structure jutting out into the lake one or two thousand feet, elevated some sixty feet above the water, and having built into the structure pockets to store the ore, accumulating cargoes in the pockets rather than in the cars; a most excellent device, the peculiar value of which we will later point out. There are twenty-five of these ore docks, the property of the different railroads, aggregating about six miles of structure, and, of course, long approaches inland to climb the necessary sixty feet. The pockets generally are about as follows:

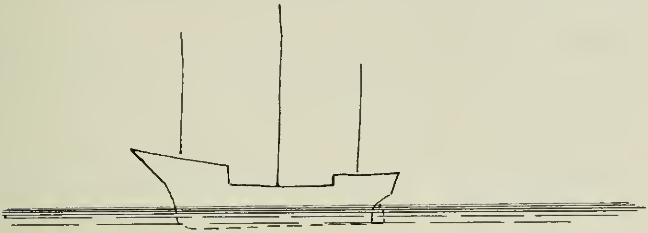


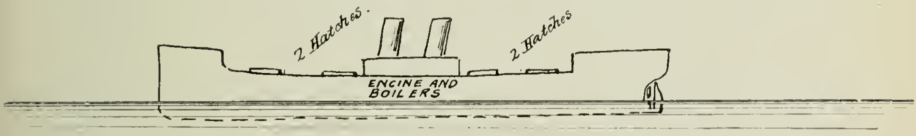
The great height is a consequence of the necessity to cause the ore to flow to the far side of the vessel, thirty odd feet. I think these pockets have been particularly described in a paper by Mr. Hatch, delivered some time last year. They are susceptible of very substantial improvement, we believe. There is no reason why the car dump, wherein the common freight car is turned upside down, found so very valuable on the lower lakes for handling coal, should not be applied at the other end of the lakes in the ore business, and there is no reason why the pockets themselves should not be so modified that they would deliver the ore more freely; the system of spouts again might be mechanically operated, and the whole dock made of steel as timber grows scarcer in the region.

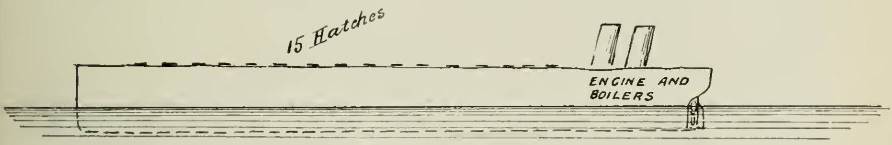
Several of these docks have already been destroyed by fire, and the insurance must be quite an item. The aggregate capacity of these pockets runs close to one million tons, so they must be filled on an average of twenty-seven times in a season like that of 1902; that is, filled and emptied every eight days, which gives a good idea of the period of time cars would be delayed if the attempt was made to load vessels directly from cars. One of the curious things about ore is the obstinacy with which it refuses to run down where one might reasonably expect it to run. Everybody must be familiar with the ordinary drop-bottom steel car, and many of you with the drop-bottom wooden car used almost altogether amongst the iron mines; but I venture to say that very few of you would believe how difficult it is to unload one of those cars. The ore being very heavy goes through a sort of packing process in transit, so that when the doors in the bottom of the cars are opened, making a hole, we will say, as big as an ordinary doorway, strange to say the ore does not run out as it ought to do, and must be humored with sledges, bars and prods and a good deal of hard work done before it consents to leave the car. My own observation is that the thirty-ton cars take, on an average, fifteen minutes to unload with half a dozen men. That same car could easily be turned over at much less expense in one minute with the familiar car-dump service. Substantial improvement might be made in these ore docks if, as much as is possible, the work were done mechanically. Time is the precious thing to be saved, especially the time of the vessel, which the climate requires to lie frozen up for four or five months of the year. Now, these vessels arrive at all hours of the day and the night, on Sundays and holidays, for there is no rest in the navigation season for the ore carrier. If the operation of the ore pockets requires a large number of men, there is, and always will be, difficulty in getting these crews out in the night or in bad weather; in fact, just when you want them, and a good deal of time is lost in this manner. There is opportunity, too, at these docks for the systematizing of the pockets themselves, a system which will lend itself to the reception and despatch of the ore, so as to require the least possible moving of the vessel to get a load. A few moments ago I spoke of the great number of ores, or names of ores existing before the creation of the United States Steel Corporation; there is a determination now, as much as possible, to reduce the numbers of ore and, regardless of their names, to mix together ores having identical characteristics. When all these ores had different owners this was not feasible. The speed with which a boat may be loaded varies, for two reasons: first and most important the condition of the ore—that is, whether it is dry and friable 'and runs, or whether it is sticky and refuses to run out of the pockets and must be coaxed out with elbow grease. The other condition, is the position of the ore in the dock itself; if a vessel arrives at the dock to be loaded with a particular kind of ore and all that ore destined for that particular cargo lies in contiguous pockets, it must be plain that a more rapid loading will be had than if that vessel could only get two pockets here and two pockets down below and some over on the other side of the dock, necessitating quite a number of movements of the vessel itself; for instance, I heard lately of a case wherein one vessel received her load within one hour, and the next vessel coming to the dock had to be moved and secured nineteen times to get a cargo, and probably took as many hours.

We have now got our ore down to the lake and presumably into the vessel. The lake vessel itself is a peculiar evolution due to its environment; that is, the absence of heavy seas, and the shortness of the voyages.

Here we have the original sea going ship, reminding you probably of the Jackson Park caravels, Columbus' vessels, feudal ideas requiring here the officers' quarters distinct from the common crew forward; the large provision necessary for quarters was required from the very large number of men necessary to work the vessel in those days; these fore and aft parts of the vessel were raised to keep the quarters dry. Next we come to the sea going tramp steamer, which is a descendant of the vessel I have sketched; here too, we find the low waist to take seas, the elevated fore and aft quarters for the reception of the crew; and the engines and boilers placed midships. The hatches themselves made as infrequent as possible, because of the heavy seas making it dangerous to have







too many hatches. Here we have a type of the lake vessel, the engines and boilers in the stern, the deck provided with numerous appliances for making fast the vessel, warping her in and out of the dock, etc., and the whole deck pierced from end to end with frequent openings for the purpose of introducing and taking out the cargo.

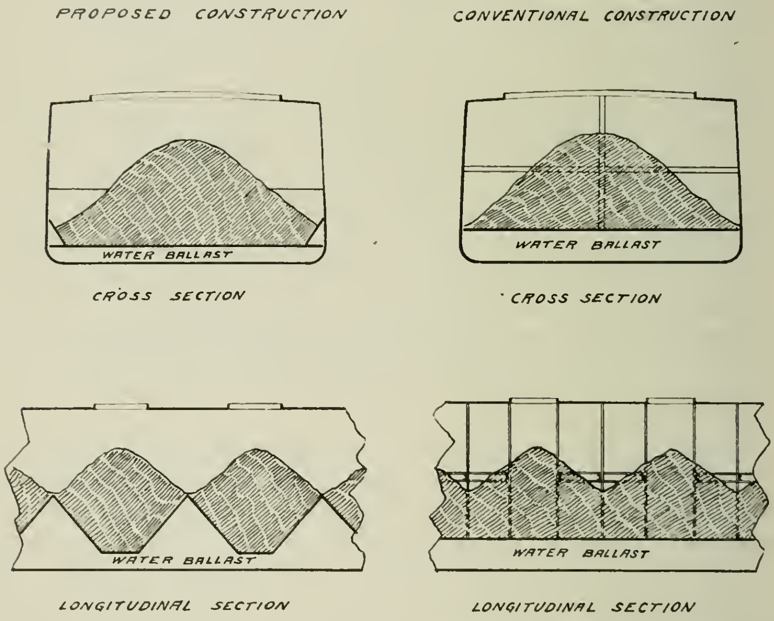
There is upon the Great Lakes a total tonnage of vessels of this character of over 1,000,000 tons, but in a year like that of 1902, it is all that such a fleet can accomplish in the short season to get the ore down to its destination.

The freight charge has averaged for a period of years about 80 cents per gross ton from Lake Superior ports to Lake Erie ports; a charge of about 20 cents a ton is made and taken out of this for merely unloading the vessel, which has always seemed to me a most absurd situation; 60 cents for carrying this ore 1,000 miles and 20 cents for lifting it 40 feet and moving it horizontally another 40 or 50 feet. The net return of the vessel per ton is, therefore, 60 cents; on a cargo of 5,000 tons we have $3,000 as the remuneration, enhanced, of course, by the occasional return load of coal. If a round trip be made in ten days, we have an earning capacity of $300 per day for this 5,000 ton vessel; so that her time is pretty valuable. It is curious to note the influence of this value of time and the other influences we have before stated, upon the construction of the ship itself and the habits of the crew, and in all respects distinguishing them from the sea going ship and its crew. It is probably a safe statement to make that a lake vessel will tie up at a dock and be ready for unloading in a twentieth part of the time which a sea going ship would take. This is perhaps a good place to point out that there is in Europe a splendid opportunity for improvement in respect to the vessels themselves and more particularly to the methods of loading and unloading iron ore. England imports something like 6,000,000 tons of iron ore per annum, a large part of this coming from Spain; 700 miles water travel from Welch ports. Ship owners have informed me that they did not average better than a trip a month between England and Spain. Our lake vessels having 1,000 miles to travel and the lock to pass through at the Soo, average ten to eleven days. Right here, there is an opportunity for the English people to cut off at least $1.00 per ton on pig iron cost, using Spanish ore; so that, after all, while we should be truly grateful for the wonderful deposits of iron ore in the Lake Superior district, we have to thank our own energy just as much for the successful and economical delivery of it to Pittsburg. Actually, so far as the natural conditions are concerned, England is more favorably placed with reference to Spanish ore than Pittsburg is with reference to Lake Superior ore, and the Englishman has the entire year for his operations.

We are quite prone to forget what a handicap our severe winters constitute. The average speed of the best class of lake vessels is probably 12 miles an hour, making 166 hours as the time needed to travel 2,000 miles; adding 16 hours, the average detention for loading and 72 hours, the average detention for unloading; we get 254 hours, or about 10½ days for the trip to Duluth and return. You will notice I provide three days time for unloading a boat; now it is very rare indeed to take more than a full day to unload a vessel in these days, but navigation is a peculiar thing; if the vessels were started out at regular intervals at Duluth, they would inevitably be bunched very soon, almost every change in the weather has the effect of bunching the fleet, just as the most petty accident will accumulate street cars in a large city; rough weather at any of the ports causes them to gather, anchored outside, waiting an opportunity to come in; the result of numerous causes of this character is that the fleet is always coming in in droves at both ends and each ship must take its turn to be either loaded or unloaded. It is this which makes the average detention 72 hours, or three days, at Lake Erie ports. Now as this 72 hours consists mostly of time spent in waiting a turn, whilst prior boats are being unloaded, it follows that any appliance which will shorten the period of time in which a boat may be unloaded not only applies to the boat itself, but also to those vessels which are waiting a turn. Now if the average period of detention be three days, it means on the lower lakes that the average vessel waited while two other boats were being unloaded for its turn to come. Now, if each of those prior boats were unloaded in one-half the time then our waiting boat would save one-and-a-half days in port.

We have shown that such a vessel is worth $300 per day, so that the effect of cutting off one and a half days' delay would be a saving of $450, a sum which, with modern appliances, would be twice as great as would be necessary to unload the whole vessel, so that really the highest economy would lead to the duplication of ore-unloading appliances and of having them idle instead of vessels. Here we have two delays; 16 hours to load and 72 hours to unload. It is the presence of the great ore pockets on the upper lakes which in a large measure account for the saving at the receiving end; they form a sort of safety valve, and there is no doubt that if a similar device was applied at the delivery end a very great saving in the vessel's time and in the uniform despatch of ore by railroads would result.

We have ourselves contemplated the construction of a lake vessel designed to facilitate unloading. A most extraordinary rate of progress is made in all these ore vessels when removing that portion which lies under the hatch opening, or which naturally flows by gravity to a point under the hatch opening. It is a common thing for a single man to remove 250 tons in an hour, quite alone, when operating on the first half of the cargo; it is the second half which is slow to get out. We, therefore, have contemplated building the vessel, having the tank top in a series of corrugations, the valley being immediately beneath the hatch openings; the sides of these valleys formed steep enough to cause the ore to positively flow. There is no doubt at all that with such a vessel a single operator will remove a hatch containing 500 tons within two and a half hours, at a cost of $3.00. Oddly enough, when we followed these designs up it was found to be a superior system of construction to the normal one of building boats.



I have here a design showing the conventional construction and also the proposed construction. The corrugations themselves form trusses transverse of the vessel, and transferring the load very evenly to the vertical sides. These corrugations also render unnecessary any posts sticking in and through the ore; they incidentally do what is very desirable in a vessel carrying such a heavy cargo, raise the center of gravity of the load, and this greatly reduces the stress on the hull in rolling, or when struck by seas; the water-tank ballast capacity is enhanced and at the same time the ease of the vessel and its carrying capacity on a given draft greatly improved, the total weight of the hull being decreased some 8 per cent.

It seems to me, now that we have taken all this ore down the lakes, I have accomplished the scope of this paper, and will be quite glad to enter into a discussion of any points involved.

DISCUSSION.

Mr. Liljencrantz—In regard to the delay in unloading vessels. Not long ago on going down to Calumet Harbor, I found nine ore-vessels lying at anchor in the outer harbor. I presume that on account of storms they had been going into different harbors all the way down, and afterwards all arrived about the same time. They have however, two harbors at Calumet, where they can unload several boats at once.

I believe you stated that there are about five months in the winter when the boats cannot run, and if I understood you right the work is going on all the year at the mines. Will those pockets hold sufficient of the winter's output from the mines?

Mr. Mason—I did not intend to give that impression. Only the underground mining goes on in the winter. The ore taken out of underground mines is not stored in those pockets, but on the ground in the vicinity of the shaft; the mine car is carried along a trestle and dumped. It is handled with a steam shovel in the spring and dispatched to the dock. It is not possible to ship ore in the winter. It would freeze.

Mr. Seddon—What is the average loading time of those boats?

Mr. Mason—This last season ought to have been better, because of the grouping of the ores I have mentioned. I was surprised to find that at the United States steel docks it had run as high as 16 hours.

Mr. Seddon—You gave a new record to me. I had heard of loading 5,000 tons in 1 hour and 58 minutes time, but you gave a record very much below that.

Mr. Mason—Yes, something under an hour.

Mr. Seddon—Unloading in about 4 hours is a record is it not?

Mr. Mason—About that.

Mr. Seddon—That is the fastest, is it not?

Mr. Mason—Yes.

Mr. Seddon—You do not know the average, I suppose?

Mr. Mason—I should say the present average was 12 hours. I mean the actual unloading.

Mr. Rainier—You brought the ore down from the dock, but you did not unload it. I have reason to believe that you have burned more midnight oil on the subject of unloading than on the other subject.

Mr. Mason—That is a very long story. I would be very glad to give you gentlemen an opportunity of seeing how it is done. It might be a good plan for all those interested to make a trip next season and see how it is done, and I now invite you to do that, and perhaps then I can convey to you much better than I could by word of mouth the way we handle the ore.

Mr. Pearce—I would like to ask if the whaleback has been used to any great extent in this class of transportation?

Mr. Mason—No; the whaleback was by no means a success. That was a case where the people ran away with an idea of economy of construction and left out the feelings of the crew. The whaleback has two decided drawbacks—no comfortable quarters for the crew, and it is difficult to get around the deck to handle in port.

Mr. Liljencrantz—There is at least one, if not two, of the whaleback forms which go down to South Chicago to the steel mill, and I know there is one or two at the steel works on the North Branch.

Mr. Mason—Yes, there are some of them in use; but they do not handle a large per cent of the business, and they are generally the very first boats to be put out of use when the dull times come.

Mr. Seddon—Have those which have gotten out into the ocean much traffic?

Mr. Mason—I think not.

Mr. Warder—You have represented a good many cross sections of vessels with practically vertical sides and flat bottom.

Mr. Mason—Yes; the lake vessels have very slight increase in size at the bottom. I will state to you, gentlemen, that the strength of this boat is in the vertical sides forming the webs of two channels, the deck and the bottom being the flanges.

Mr. Warder—Then the deck structure between the hatch and the guard is an important element?

Mr. Mason—Yes, most important. It is kept as light as it is possible to make it and furnish the metal for flange. It is generally kept about seven feet wide.

Mr. Warder—Then the use of structural metal in that seven feet is to get as much stiffness as possible?

Mr. Mason—Yes; just like a channel.

Mr. Warder—The stiffness is introduced on the edges, I suppose?

Mr. Mason—Yes: that is one of the troubles. They put in bulkheads, forming diaphragms, as it were, to assist in giving stiffness to the hull; then there is a girder in the tank bottom, from end to end, and then beams across to carry the load.

Mr. Liljencrantz—About what is the value per ton of ore at South Chicago, coming from the Lake Superior mines?

Mr. Mason—I think it is from $3.00 to $3.50.

Mr. Liljencrantz—The reason I ask is this—not long ago the steamer Wawatam went aground about two miles south of the Lake View water works crib. I went out there to look into matter, and found what I think was a stone dump, with only 13 feet of water over it, but the captain managed to find that place. All around the boat there was 22 feet of water. They had to dump overboard from 400 to 500 tons of ore, and the captain said it would be too expensive to send a dredge up to take it out—that it would cost about $4.00 a ton to do that; another party told me it was worth about $1.00 a ton to do that work.

Mr. Mason—I have stated that the freight is 80 cents; if from an underground mine of hard ore, it must have cost $1.00 or $1.50 to mine; it is then taken 75 miles by rail; that added 50 cents, making $1.75; at the shipping dock it had to bear 80 cents freight, which would make about $2.50. The person who owned the land had to get something, so you can see there was easily $3.00 in sight.

Mr. Seddon—Some of the ore has 60 per cent iron, has it not?

Mr. Mason—Some of it, but not all. I presume the Missabe range would have 55 per cent iron, and that is probably the richest. The others would hardly reach 50 per cent.

Mr. Seddon—Is there no selection at all?

Mr. Mason—Yes, constant selection. Often a single car has to run the gauntlet of several analyses.

Mr. Seddon—Do they not skip any of the ore in the pit and leave it there?

Mr. Mason—No; that would not be practicable, because right beyond what they leave might be a very high grade ore.

Mr. Rainier—You spoke of the probability of those ore docks being built of steel, some time in the future, on account of the danger of their burning down. Have you any figures on the relative cost of steel docks as related to wooden docks?

Mr. Mason—No I have not. There would be this disadvantage—that the steel construction would cause the ore to freeze much more rapidly than with wood construction, and late and early in the season frost would be a serious difficulty.

Mr. Liljencrantz—It seems to me that when such expensive cargoes are sent down, carrying 4,000 to 5,000 tons of ore, they ought to be very careful in the selection of their captain. Last year the captain of a certain steamer went right through the breakwater in Calumet Harbor. The breakwater is 30 feet wide, filled with stone, and he cut through to a depth of 18 feet below the water level and 6 feet above. He came along at a speed of 12 miles an hour. He claimed that there was a dense fog and that the fog horn was not being worked, but it is suggested that a captain who will enter a harbor in a dense fog at the rate of 12 miles an hour should not be trusted with an expensive vessel and cargo.

SOME POINTS IN BRIDGE DESIGN.

Presented March 16, 1904.

EFFECT ON TRUSSES AND PLATE GIRDERS DUE TO IMPERFECT ROLLER-SUPPORT.

Geo. N. Linday, M. W. S. E.

Some years ago a case was mentioned in an engineering journal of the damage done to a highway span on account of the sudden collapse of an I-beam pedestal supporting the end of the truss on the masonry. The I-beams were placed transversely to the length of the bridge, and coverplates were riveted to the top and bottom flanges of the beams. After the failure it was found that the top flanges had been pulled forward without changing their horizontal position, while the bottom flanges had remained in place, and that subsequently the weight of the bridge had mashed the pedestal down, bending the webs of the beams along a reverse curve and throughout their entire length, as indicated by the sketch, Fig. 1.

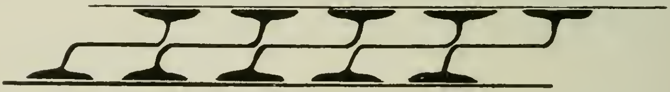
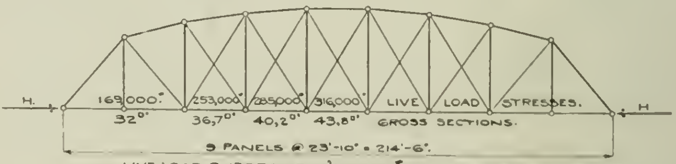


FIG. 1.

Such a failure was evidently due to the fact that the end of the bridge, which was originally designed to permit a change of span length, due to strain and temperature, had become immovable through the failure of the expansion rollers to act as intended. The horizontal resistance introduced on this account was large enough to pull the pedestal over. That it had taken considerable strain to bring about such result is evident and the effect on the trusses and the piers shortly before the collapse must have been something quite different from that the designer thought he would have under ordinary circumstances.

To get some notion what a truss has to stand, if for some reason the ends have become immovable, it might be interesting to see what some speculating on the subject would lead to. Take a truss as shown in Fig. 2. It belongs to a bridge actually built and in use today.



LIVE LOAD 2-139 TON ENG'S. & 3200# PR LIN FT OF TRACK.

FIG. 2.

Any vertical load placed on the truss after the rollers have become ineffective will produce a horizontal reaction, and it will naturally be in the nature of a push-out on the piers due to the stretching of the bottom chord. An increase of temperature will have a like effect (a decrease of temperature the opposite), and a yielding of the pier on account of these effects will again modify the stress condition in the truss and the push on the pier. In other words the truss has become a statically indeterminate structure and any problem relating to it can then be solved by an application of the law of virtual work. In the following the general method as laid down by Prof. Mueller-Breslau in his "Neuere Methoden der Festtigkeitslehre" has been used in working out the results given. This book, by the way, gives in a compact form a comprehensive idea of the application of this law to elastic structure. If the horizontal reaction were known, the stresses throughout the truss could be found; hence it is statically indeterminate in the first degree, and for such a truss the effect on the horizontal reaction

due to vertical loads, is $H_1 = -\dfrac{\Sigma S_0 . S_1 \frac{l}{A}}{\Sigma S_1^2 . \frac{l}{A}}$

due to a temperature change $H_2 = -\dfrac{E.e\,t\,\Sigma S_1 l}{\Sigma S_1^2 . \frac{l}{A}}$

due to a yielding of the pier $H_3 = -\dfrac{E.y}{\Sigma S_1^2 . \frac{l}{A}}$

Here the various letters have the following meaning:

H, horizontal reaction counted positive in the direction towards the center of the span.

S , stress in any member for a given loading when H = 0, or in other words when the end is free to move.

S_1, stress in any member for H = 1 applied in a positive direction (see Fig. 2) while all other loads are removed.

l, length of any member in the truss. A, its gross section area.

E, modulus of elasticity = 29,000,000 pounds.

e, coefficient of expansion for steel $= \frac{1}{151000}$. Hence E.e = 192

t, change of temperature, positive or negative.

y, yield of pier or change of span length due to such yielding.

For the case under consideration the various expressions for H can be simplified a good deal, because S_1 is zero for all members in the truss except the bottom chord members, which all get a stress $S_1 = -1$; and as, furthermore, all the panels are of the same length, the expressions for the various horizontal reactions become:

$$H_1 = \frac{\Sigma \frac{S_0}{A}}{\Sigma \frac{1}{A}}$$

$$H_2 = \frac{Eetn}{\Sigma \frac{1}{A}}$$

$$H_3 = -\frac{E.y.}{l.\Sigma \frac{1}{A}}$$

where n represents the number of panels = 9, and the summations extend over the bottom chord members only. It is safe to say that when the bridge is first erected the rollers are in good working order, so that the truss is allowed to take the shape due to dead load and vertical reactions only. Even if, subsequently, the rollers become immovable by rusting fast or getting skewed, the dead load will never have any effect horizontally. When the live load then passes over and the bridge is fully loaded, the effect on H, is (no impact considered)

$$H_1 = \frac{4\times\frac{169000}{32{,}0} + 2\times\frac{253000}{36{,}7} + 2\times\frac{285000}{40{,}2} + \frac{316000}{43{,}8.}}{4\times\frac{1}{32{,}0} + 2\times\frac{1}{36{,}7} + 2\times\frac{1}{40{,}2} + \frac{1}{43{,}8.}}$$

$$\text{or } H_1 = \frac{56300}{0{,}252} = \underline{\underline{224{,}000 \text{ LBS}}}.$$

One peculiarity to be noticed here is that if all the sections in the bottom chord were alike, we have

$$H_1 = \frac{\Sigma S_0}{\Sigma 1} = \frac{\Sigma S_0}{9}.$$

In other words the horizontal push is the same as the average stress in the bottom chord. The average for this case is 229,000 pounds, which is only 2 per cent in excess of the more correct figure. Another peculiarity is that H_2 is apparently independent of the span length. But it is easily seen that the formula for H_2 is correct if the same assumption of equal sections is made when H_2 becomes

$$H_2 = E\,e\,t\,A, \text{ or } \frac{H_2}{A} = E\,et$$

The left side is evidently the unit stress in the section, produced by H_2, and $\frac{H_2}{AE}$ is the distortion (et) per unit of length, which would take place if freedom of movement was not restrained.

The effect of an increase of temperature of 1 degree is

$$H_2 = \frac{192 \times 9}{0.0252} = 6870 \text{ pounds.}$$

An increase of 50 deg. above the temperature which prevailed at the time the roller end became immovable would then be

$$H_2 = 343000 \text{ pounds.}$$

This looks like an enormous stress, but when it is remembered that, if the ends were free to move the expansion due to this change of temperature would be $\frac{214.5 \times 12 \times 50}{151000} = 0.85$ inch, it evidently must take an enormous force to altogether prevent such movement. The total effect of full live load and an increase of temperature of 50 deg. would then be $H_1 + H_2 = 572{,}000$ pounds. But this is more than the combined maximum live and dead load stress in the bottom chord which amount to 516,000 pounds.

As it is not likely that the stress throughout the bottom chord will be reversed, it is certain that something must yield before this horizontal end push is reached. The vertical reaction from live and dead load is 392,000 pounds and hence, if the friction between steel and masonry is 0.4, the total frictional resistance becomes 392,000 x 0.4 = 157,000 pounds. If after this resistance has been reached the piers still remain immovable or nothing else has yielded under its influence, then the span ends will slide on the masonry and the push will never exceed 157,000 pounds. The movement that must take place in order to limit the push to this amount can be figured from the expression for H_3 by putting $H_3 = 572000 - 157000 = 451000$, and solving for y, which then become numerically

$$y = \frac{451000 \times 23.83 \times 12 \times 0{,}252}{29{,}000{,}000} = 0.986 \text{ inch or 1 inch practically.}$$

Whether the movement is by sliding on the pier, or by the rocking or yielding of the pier is of course immaterial as far as the effect of the movement is concerned. It is probable that the movement would be made up of both kinds. Under any loading or temperature change assumed the upper limit of the horizontal resistance, can in this manner be ascertained.

Calculations similar to those given here for a truss, can be made for a plate girder. One difference in the effect on the two kinds of structures is that the horizontal resistance, if developed, affects only the bottom chord in a truss but modifies the stresses throughout the whole section in a plate girder.

By applying the same general principle of virtual work, upon which the formulas for trusses were derived, to a girder, expressions for the various values of H are obtained as follows:

$$H_1 = \frac{1}{12} \cdot \frac{w.d.l^2}{r^2 + d^2}$$ for full uniform load w.

$$H_1 = \frac{1}{2} \cdot \frac{Pabd}{l(r^2 + d^2)}$$ for a concentrated load P, located distances a, and b, from the ends.

$$H_2 = \frac{E.e.I_o.t.}{r^2 + d^2}$$

$$H_3 = -\frac{E.I_o.y.}{l(r^2 + d^2)}$$

In addition to the notations already used these formulæ contain the following:

r, is the average vertical radius of gyration of girder;
d, is the half depth of the girder b. to b. of flange angles;
I_o, is the average moment of inertia of the girder;
l, is the length of span between centers of supports.

An average moment of inertia I of a girder with varying cross-section on account of the different lengths of cover plates, is obtained by putting, approximately

$$I_o = \frac{\Sigma I.c}{l}$$

where I represents the moment of inertia for the part c, of the length l, of the girder. In the same manner the average cross-section A_o can be figured from

$$A_o = \frac{\Sigma A.c}{l}$$

and finally the average r from

$$r^2 = \frac{\Sigma I.c}{\Sigma A.c}$$

Let us take as a numerical example a 100-foot deck plate girder, 97 feet 8 inches between centers of supports, 9 feet deep over angles, with each flange composed of two 8-in. x 8-in. x ⅞-in. angles, and with three cover plates 18-in. x ⅝-in x 76 ft., 64 ft., and 46 ft. long, respectively; the web plate being 108-in. x ⅜-in. The same live load as used for the truss will produce a maximum moment of 3,093,000 foot pounds, which is equivalent to the effect of 2,600 pounds uniform load = w.

The other constants are I $= 306190$ and $A_0 = 136$ in inches, hence $r^2 = 2270$ or $r^2 = 15.7$ in feet.

The horizontal effect due to live load is then

$$H_1 = \frac{1}{12} \cdot \frac{2600 \times 4{,}5 \times 97{,}67^2}{15{,}7 + 4{,}5^2} = \underline{258{,}000^{\#}}$$

An increase of 1 deg. of temperature will make

$$H_2 = \frac{192 \times 306190}{2270 + 54^2} = \underline{\underline{11340^{\#}.}}$$

and for 50 deg. equals 567,000 pounds.

A yield of the pier of ¼-inch would produce an effect of

$$H_3. = \frac{2.900000 \times 306190 \times 0{,}25}{97{,}67 \times 12 \times (2270 + 54^2)} = \underline{\underline{366{,}000^{\#}.}}$$

It will be noticed that all the horizontal resistances in this case are considerably larger than for the truss, which may seem strange; but the explanation is that the masses of metal affected are a good deal larger, so that the internal work by direct stress and bending, that must be done to prevent any horizontal movement, must necessarily be large. A very small yielding or movement by or on the pier will, however, greatly relieve the pressure. Again, the frictional resistance is considerably smaller, so that the chance for movement is correspondingly large.

Whatever the relieving and yielding of the piers or movement thereon may be, it is clear that the horizontal resistance from imperfect roller supports must be considerable, and that it is not only to take care of the traction effect that it is good policy to make part or all of a bottom chord, stiff members. These speculations also show the necessity of using large rollers that will readily move under the expanding or contracting tendency of the span, and that small rollers, on account of their liability to get stuck easily, are worse than useless.

I have stated on page 124 that the length of span has nothing to do with the amount of horizontal pressure that it exerts on the immovable support on account of a change of temperature. Another illustration of that fact should be: if we had, for instance, a post fitted in tight between the floor and the ceiling, as in the case of a brace in a mine. No matter if this brace is 5 or 50 feet high, it would, for an increase of temperature, press the same amount against the floor and ceiling, provided it had the same cross-section and remained straight. If, again, one had double the section of the other, it would press twice as hard, even if it happened to be the short one. If the top were free to move, the amount of movement would be independent of the section, but proportional to the length. While if it is thus restrained the pressure is independent of the length, but proportional to the section.

There is another thing about this roller business that is puzzling. How is it possible that roller nests ever get skewed, which they sometimes do? I don't suppose there is a span provided with rollers that has got a dead load at each corner of less than eight or ten tons. When the live load gets on, the pressure will be considerably more. Still, turning movement takes place. One explanation that I would venture to make is this: A bridge is a structure that is supported on four points, the same as a chair. As three points determine a plane, it is several millions to one that the fourth point does not lie in the same plane as the other three. If the bridge seats were in absolutely the same plane, we can readily see that two diagonal corners do not press down on the masonry as hard as the other two diagonal corners. We can imagine a case, where we have very solid sway bracing and floor connections and where the masonry is not true to the proper grade, in which one corner does not bear at all. When the live load comes on from the opposite end of the bridge, there will be a violent vibration laterally of the suspended corner, so to speak. This vibration might be sufficient to dislocate the rollers a trifle. Repeated a few thousand times, these movements will amount to something and in the long run cause a turning of the roller nest.

I have called attention in the paper to the fact that the horizontal thrust for a 100-foot plate girder is more than for a 200-foot truss, and in a general way ventured an explanation. I have since thought of another way to look at it, which is this: A plate girder with immovable ends is in the same fix as a two-hinged solid web arch with a rise of half the depth of the girder. In the example given, say the span length is 100 feet and the rise 4.5 feet, which gives a ratio of between 20 and 25 feet. Such an exceedingly flat arch will, of course, produce extraordinarily large horizontal thrusts, due to any cause.

In the case of the truss the bottom chords can be compared with a column which is directly compressed to the amount of the horizontal pressure of the masonry.

DISCUSSION.

Mr. Modjeski, M. W. S. E. (by letter)—Mr. Linday's paper is of interest and of value because it calls attention to the importance of good design of expansion bearings. Although there is generally far more care shown now in providing for proper expansion of metal structures than there was ten or fifteen years ago, the importance of this detail is still too often underrated. The following case which the writer had occasion to report upon may be of interest. In an existing bridge a granite pier supports two expansion bearings of the two adjoining 400-foot spans. This pier was originally built with the central portion between the bearings projecting above the level of end pins, the object being to provide a lateral guide for the end shoes. On this block of masonry, opposite the pins, vertical guide plates were attached while cast guide blocks were screwed on the end of the pins. The play between these guide blocks and plates was very small. The end floorbeams are connected rigidly to the shoes. During a very cold winter some of the granite blocks extending across the pier in the central portion were found broken and pulled apart several inches. The writer's explanation is that the end floorbeams, contracting, took up all the play allowed between the guide blocks on the piers and the vertical plates on the masonry producing sufficient friction to prevent sliding; the bottom chords of the adjoining spans then continued to contract in opposite directions, wrecking the masonry.

The writer observed several times the rocking of piers under passing trains when the roller bearings were not in working order. This is due of course to the change in length of the bottom chord under load.

It is quite fortunate for the metal structures with defective roller bearings that when the effect of temperature stresses in the bottom chords is of the same sign as the effect of live load, the former is reduced by the application of live load owing to the deformation of the chord, and that when the effect of temperature stresses in the bottom chords is of opposite sign to the effect of live load, although the former is increased by the application of the live load, the resultant stresses being of opposite sign the algebraic sum seldom exceeds permissible stresses. This may account for the scarcity of failures of bridges on account of ineffective expansion bearings, except failures in the bearings themselves, such as the instance given by the author of the paper.

Not so with the masonry which is not designed for alternating horizontal stresses. It is here that damage generally appears and it is to avoid this damage more than any possible abnormal stresses in the metal that great care should be exercised in providing properly designed expansion joints and bearings.

No rollers less than 5 inches or 6 inches in diameter should ever be used. The writer uses now 9-inch segmental rollers on plate girders from 60 to 100 feet and 12-inch segmental rollers for spans above 100 feet. On very long spans larger rollers even should be used. 15-inch rollers were used in the Memphis and 18-inch will be used in the Thebes bridges.

The roller bed should be placed above the masonry at a reasonable height, never less than 6 inches and if practicable 12 inches or more. This is for the purpose of keeping it clear from cinders and dirt. The slight additional expense of a well designed bearing will be more than repaid in the saving and preservation of the masonry, not speaking of the greater security of the metal structure.

Mr. J. W. Schaub, M. W. S. E. (by letter)—Referring to the paper by Mr. George N. Linday, M. W. S. E., regarding the effect on trusses and plate girders, due to imperfect roller bearings, the author no doubt refers to the failure of an I-beam wall plate, or pedestal, which failed in a bridge at Hamilton, Ohio, during January, 1899.

The fixed load on this pedestal was about 825,000 pounds, so that the work called upon to do by the I-beams was considerable. The beams were unsupported sideways, being free to fail in either direction. As the top of the pedestal moved away from the abutment, the failure was not due to a movement of the abutment, as is common in such cases, but was undoubtedly due, indirectly, by the rollers at the other end of the bridge not being free to move, as stated by the author. However, there are many bridges in use in this country to-day in which the rollers do not move, for various reasons, and so far no serious difficulty has arisen on this account.

The writer remembers examining a bridge on a western road in 1885 which had no rollers whatever, although the bridge was 100 feet long—a deck span with vertical end posts. To be sure, the effect of temperature changes and loading caused something to happen; and what happened was, that the end bottom chord, which was a stiff member, composed of two 6-inch channels about 17 feet long, was distorted permanently about 4 inches out of line, and every time a train moved over the bridge at high speed this member would yield very gracefully, very much like a wagon spring. What would have happened in case this member failed, the writer is not prepared to say; it is sufficient, however, to say here that the bridge was put on false work immediately

Quite recently, on another railroad, the writer found a number of spans 200 feet long in which the rollers, only 2 inches in diameter, were so badly skewed as to preclude the possibility of their moving, and the result was that the spans would slide back and forth on the tops of these rollers without any difficulty whatever.

In another case, segmental rollers 12 inches in diameter under spans 440 feet long, double track, were found in a condition showing that the rollers did not roll back into a normal position, and had to be straightened up once every year. The most curious thing in regard to this latter case is that the rollers are invariably found in a position inclined away from the end of the span. In any form of segmental roller, it can be shown that the deformation of the roller, when in a vertical position, is entirely different from the deformation when the roller is in an inclined position, and this theory is confirmed by the fact that the rollers in this case are always found in a position inclined away from the ends of the span. Assuming the rollers to stand plumb, any changes due to temperature, from day to day, would be inappreciable compared to the extent of increase in the length of the bottom chord when the load comes on, so that the first appreciable movement of the rollers takes place when the moving load first comes on the span, and then the movement of the rollers is always in one direction; that is, away from the end of the span. To be sure, the rollers may recover some of this movement, but probably not all of it, because they have suffered their greatest deformation when the load is on the span, the rollers being then in an inclined position; and, in order to roll back, they must lift the end of the span by an amount equal to the difference between the vertical deformation of the rollers when inclined and when standing plumb, which they evidently cannot do, owing to the span being free to slide over the tops of the rollers. In other words, when the end of the span moves it goes down hill, and never comes back all of the way. This action is cumulative, and shows its results as stated. It must be borne in mind that it takes over a year to produce any appreciable results in the position of the rollers, so that the action of a single load passing over the bridge would be inappreciable. In this case, the friction to slide cannot be great, for it can be shown that the co-efficient which resists sliding must be less than 0.10.

It might be well to speak here of the danger connected with the use of segmental rollers in turning completely over. As commonly designed, segmental rollers are prevented from overturning by a sidebar with a hook at each end. If this hook fails, or the bolts attaching the bars to the ends of the rollers are sheared off, there is nothing to prevent the end of the span from coming down, hence it is of the utmost importance that segmental rollers, as commonly designed, should not be permitted to get very far out of plumb.

If the sides of the segmental rollers are made plane surfaces, it is possible to design a segmental roller which will not overturn under any circumstances, and such rollers have been designed by the writer and are now used in a number of bridges since 1899.

In any event, the writer has never found any case in which the ends of a span were held rigidly enough, so as to prevent a free movement of the pier under it; and, in several cases it has been found that the pier or abutment has been moved out of line from under span, so that the friction which is overcome could not have been of any serious moment. To be sure in the case of the bridge noted by the author something did happen, but it is doubtful if anyone would have been the wiser if the I-beam pedestal had been properly designed.

RAILWAY BRIDGE CALCULATION BY END SHEAR TABLE.

By Josiah Gibson, M. W. S. E.

We have before us a method for the calculation of stresses in girders and trusses which will greatly facilitate speed and accuracy. The tables here given are calculated for one rail and using a loading of two 188.5 tons engines followed by 5,000 pounds per linear foot of track. This is the new standard loading of the Northern Pacific Railway.

The tables give the end shear in thousands of pounds for that portion of the load which would come on the span given, to the left or the right of the wheel indicated, but this end shear does not include the wheel load at the point. Table 1 gives end shears up to a span of 50 feet. Table 2 gives end shears of each alternate span length from 52 feet to 150 feet inclusive. End shears for spans omitted in table 2 can be obtained by interpolation.

In these tables the position of maximum reaction is indicated by a line above the figure. The position of maximum reaction for two successive spans is indicated by a plus sign between the figures. There is always one position shown for each condition under each span. There may be two or more positions shown which give the same result. Thus:

If we refer to the 40-foot span, table 1, we see that the position of maximum end reaction is when wheel 2 or wheel 11 is at the left of the span. The end shear of the load on the span is 72,900 and the wheel load is 26,000, which is a total of 98,900 as the maximum end reaction. We also see by the plus sign that when wheel 13 is at the point of support between the two successive spans the reaction at this point is the greatest and is equal to 59,500 for span to left of wheel 13 and 56,300 for the span to right and a wheel load of 26,000, which gives a total load of 141,800 pounds for one rail.

We may vary this by the following problem:

Find the maximum live load reaction on the pier between a 120-foot and a 140-foot span. The plus sign indicates that wheel 15 gives the maximum between two 120-foot spans and wheel 17 gives the maximum between two 140-foot spans.

If we add the separate results for 120-foot spans to those for 140-foot span under wheel 15 and likewise under wheel 16 and 17, always adding a left hand result to a right hand result, we will find the maximum. Thus: For a 120-foot span to the left of wheel 15 there is an end shear of 185,000 and for a 140-foot span to the right of wheel 15 an end shear of 178,500 and a wheel load of 18,000, which is a total of 381,500 pounds live load for one rail.

We will now take up a method for finding flange stress from the table. Any span can be divided into two equal or unequal parts. The reaction of the loads on the span are now found at the point of division. The reaction thus found is an equivalent concentrated load, which applied at the point of division will give the same bending moment at this point as is given by the loads on the span. If the load thus found was a maximum, then the moment given by this concentrated load is a maximum moment for this point.

The above method of determining a maximum moment can be used at any panel point on a through span. The method can be used on any deck span and will give a maximum moment at that point but not necessarily for the span. In deck spans, after finding the position which will give the maximum at the center of the span, we can move the load until its position meets the requirements for maximum moment and then find the moment.

These remarks can best be illustrated by assuming some problem as will follow. While a through girder has been taken, yet much of the calculation of a through truss span is similar.

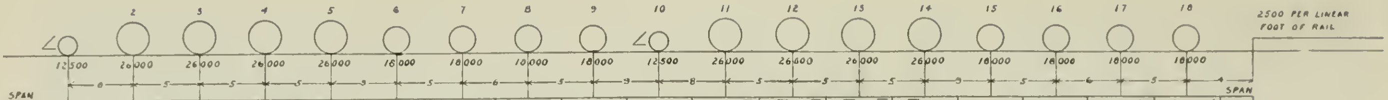
Find the live load stresses in a 90-foot through plate girder span which has stringers, 7-foot centers and the girders 15-foot centers. The span to have five panels at 18 feet each.

For maximum moment of 18-foot stringers, look for maximum reaction of two successive 9-foot spans which the plus sign shows occurs at wheel 3, 4, 12 and 13. The reactions are 11,600, plus 11,600, plus a wheel load of 26,000, or a total of 49,200 and the moment is 49,200 times 18, divided by 4, equals 221,400-foot pounds. It will be observed that the position of this load is correct for maximum moment and so it need not be moved.

Maximum end reaction for 18-foot stringer occurs at wheel 2, 5, 11 or 14, and is 34,700, plus a wheel load of 26,000, equals 60,700. Distance between stringer and girder is 4 feet. Maximum moment for end floor beam is 60,700 times 4, equals 242,800-foot pounds.

Maximum load for intermediate floor beam between two 18-foot spans occurs when a wheel 4 or 13 is over the floor beam and is 30,300, plus 22,800, plus 26,000 wheel load, which equals 79,100. Maximum moment for intermediate floor beam is 79,100 times 4, equals 316,400 foot pounds.

Maximum end reaction for 90-foot girder is when wheel 2 is at the end of girder and is 153,500, plus 26,000, which is 179,500. For maximum moment at first panel point we compare an 18-foot span with a 72-foot span and find wheel 4, 11, 12 or 13 will give the maximum. We will also include wheel 3 in our comparison as there is very little difference between wheel 3 and 4 for 18-foot span. An 18-foot span to the left of wheel 3 gives 22,300 and a 72-foot span to the right gives 114,500 and a wheel load of 26,000, which is a total concentrated load of 162,800 pounds. The maxi-



SPAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	SPAN
6		4.3	4.3 + 4.3	4.3 + 4.3	4.3	3.0	3.0	3.0	3.0		4.3	4.3 + 4.3	4.3 + 4.3	4.3	3.0	3.0	3.0	3.0 8	6
7		7.4	7.4 + 7.4	7.4 + 7.4	7.4	5.1	5.1 2.6	2.6 5.1	5.1		7.4	7.4 + 7.4	7.4 + 7.4	7.4	5.1	5.1 2.6	2.6 5.1	5.1 1.6	7
8		9.8	9.8 + 9.8	9.8 + 9.8	9.8	6.8	6.8 4.3	4.5 6.8	6.8		9.8	9.8 + 9.8	9.8 + 9.8	9.8	6.8	6.8 4.5	4.5 6.8	6.8 2.5	8
9	2.9	1.4 11.6	11.6 + 11.6	11.6 + 11.6	11.6	8.0	8.0 6.0	6.0 8.0	8.0	2.9	1.4 11.6	11.6 + 11.6	11.6 + 11.6	11.6	8.0	8.0 6.0	6.0 8.0	6.0 3.5	9
10	3.2	2.5 13.0	13.0 + 13.0	13.0 + 13.0	13.0 1.8	2.6 9.0	9.0 7.2	7.2 9.0	9.0 1.5	1.8 5.2	2.5 13.0	13.0 + 13.0	13.0 + 13.0	13.0 1.8	2.6 9.0	9.0 7.2	7.2 9.1	9.0 4.5	10
11	7.1	3.4 16.5	14.2 + 16.5	16.5 + 14.2	16.3 3.3	4.7 9.8	9.8 8.2	8.2 9.8	9.8 2.3	3.3 7.1	3.4 16.3	14.2 + 16.5	16.5 + 14.2	16.5 3.3	4.7 9.8	9.8 8.2	8.2 10.3	9.8 5.6	11
12	8.7	4.2 19.5	15.2 + 19.5	19.5 + 15.2	19.5 4.5	6.5 12.0	10.5 10.5	10.5 10.5	12.0 3.1	4.5 8.7	4.2 19.5	15.2 + 19.5	19.5 + 15.2	19.5 4.5	6.5 12.0	10.5 10.5	10.5 11.4	12.0 6.7	12
13	10.0	4.8 22.0	16.0 + 22.0	22.0 + 16.0	22.0 5.5	8.0 13.8	11.1 12.5	12.5 11.1	13.8 3.8	3.5 10.6	4.8 22.0	16.0 + 22.0	22.0 + 16.0	22.0 5.3	8.0 13.8	11.1 12.5	12.5 12.6	13.8 7.8	13
14	13.0	5.4 24.1	17.6 + 24.1	24.1 16.7	24.1 6.4	9.3 15.4	11.6 14.1	14.1 11.6	15.4 4.5	6.4 13.0	5.4 24.1	17.6 + 24.1	24.1 16.7	24.1 6.4	9.3 15.4	11.6 14.1	14.1 15.8	15.4 8.9	14
15	15.6	5.8 26.0	19.0 + 26.0	26.0 18.5	26.0 8.4	12.1 16.8	13.7 15.6	15.6 12.8	16.8 5.0	8.4 15.6	5.8 26.0	19.0 + 26.0	26.0 18.5	26.0 8.4	12.1 16.8	13.7 15.6	15.6 15.0	16.8 10.1	15
16	17.9	6.3 29.3	20.2 + 27.6	27.6 20.1	29.3 10.1	14.6 18.0	15.6 16.9	16.9 13.9	18.0 5.5	10.1 17.9	6.3 29.3	20.2 + 27.6	27.6 20.1	29.3 10.1	14.6 18.0	15.6 17.0	16.9 16.2	18.0 11.3	16
17	19.9	6.6 32.1	21.3 29.0	29.0 + 21.5	32.1 11.6	16.8 20.1	17.3 18.0	18.0 14.9	20.1 5.9	11.6 19.9	6.6 32.7	21.3 29.0	29.0 + 21.5	32.1 11.6	16.8 20.1	17.3 18.3	18.0 17.4	20.1 12.4	17
18	21.7	6.9 34.7	22.3 30.3	30.3 + 22.8	34.7 13.0	18.8 22.0	18.8 19.0	19.0 15.8	22.0 7.7	13.0 21.7	7.3 34.7	22.3 30.3	30.3 + 22.8	34.7 13.0	18.8 22.0	18.8 19.6	19.0 18.6	22.0 13.6	18
19	24.6	7.2 36.9	23.1 31.5	32.1 + 23.9	36.9 14.2	20.5 23.7	20.1 19.9	19.9 16.5	23.7 9.3	14.2 24.6	9.1 36.9	23.1 31.5	32.1 + 23.9	36.9 14.2	20.5 23.7	20.1 20.9	19.9 15.8	23.7 14.7	19
20	27.3	7.5 39.0	23.9 33.4	33.8 + 25.8	39.0 15.3	23.4 25.2	22.6 20.7	20.7 17.3	25.2 10.8	15.3 27.3	10.2 39.0	23.9 33.4	33.8 + 25.8	39.0 15.3	23.4 25.2	22.6 22.3	20.7 21.1	25.2 16.0	20
21	29.7	7.7 40.9	24.6 35.1	35.2 + 27.5	40.9 17.1	25.0 26.6	24.9 22.0	22.7 17.9	26.6 12.1	17.1 29.7	11.2 40.9	24.6 35.1	35.2 + 27.5	40.9 17.1	25.0 26.6	24.9 23.6	22.7 22.3	26.6 17.2	21
22	31.9	8.0 42.5	25.2 36.7	36.5 + 29.1	42.5 18.8	28.4 27.8	26.9 23.2	24.5 18.5	27.8 13.3	18.8 31.9	12.0 42.5	25.2 36.7	36.5 + 29.1	42.5 18.8	28.4 28.0	26.5 24.9	24.5 23.5	27.8 16.4	22
23	33.9	8.2 46.1	25.8 38.2	37.8 + 30.5	44.1 20.3	30.5 29.0	28.8 24.3	26.1 20.1	29.0 15.5	20.3 33.9	13.6 44.7	26.6 38.2	37.8 + 30.5	44.1 20.3	30.5 29.4	28.8 26.2	26.1 24.7	29.0 19.6	23
24	36.0	8.3 45.5	26.3 39.5	38.9 + 31.8	46.0 21.8	32.5 30.0	30.5 25.3	27.6 21.6	30.0 17.6	21.8 36.8	15.1 45.5	27.8 39.5	38.9 + 31.8	46.0 21.8	32.5 30.8	30.5 27.5	27.6 26.0	30.0 28.8	24
25	39.5	8.5 47.5	26.8 41.4	39.9 + 33.0	47.8 23.0	35.4 31.0	33.1 26.3	29.0 23.0	31.0 13.4	23.0 39.3	16.4 47.5	29.0 41.4	39.9 + 33.0	47.8 23.0	35.4 32.2	33.1 20.8	29.0 27.2	31.0 22.1	25
26	42.0	8.7 49.4	27.3 43.2	40.8 + 35.0	49.4 24.9	38.0 32.3	35.5 27.1	31.2 24.3	32.8 21.2	24.9 42.0	17.7 49.4	30.0 43.2	40.8 + 35.0	49.4 24.9	38.0 35.6	35.5 30.5	31.2 27.7	32.8 23.3	26
27	44.5	8.8 51.7	27.7 44.9	41.7 + 36.5	51.0 26.7	40.4 33.6	37.8 27.9	33.3 25.5	34.6 22.8	26.7 44.3	18.8 51.1	31.0 44.9	41.7 + 36.5	51.0 26.7	40.4 34.9	37.8 31.3	33.5 29.7	34.6 24.5	27
28	46.4	8.9 52.7	28.1 46.4	42.5 38.1	52.4 28.3	42.7 34.8	39.9 28.6	35.3 27.5	36.2 25.2	28.3 46.4	19.9 52.7	32.6 46.4	42.9 + 38.1	52.4 28.3	42.7 36.3	39.9 32.6	35.5 30.9	36.2 23.7	28
29	48.4	9.1 54.2	28.4 47.9	43.3 39.5	53.7 29.8	44.8 35.9	41.8 30.2	37.1 29.4	37.7 27.4	29.8 48.4	21.5 54.2	34.0 47.9	44.5 + 39.5	53.7 29.8	44.8 37.6	41.8 33.9	37.1 32.1	37.7 26.9	29
30	50.3	9.2 56.2	28.8 49.2	44.0 40.9	54.9 31.2	46.8 36.9	44.5 31.7	38.8 31.2	39.1 29.6	31.2 50.3	23.0 56.2	35.4 49.2	45.8 + 40.9	54.9 31.2	46.8 39.0	44.5 35.2	38.8 33.4	39.1 28.2	30
31	52.0	9.3 58.1	29.1 51.0	44.7 42.7	56.1 32.5	48.6 37.8	47.0 33.1	41.2 32.9	41.3 31.5	32.5 52.0	24.4 58.1	36.6 51.0	47.0 + 42.7	56.1 32.7	48.6 40.3	47.0 36.5	41.2 34.6	41.3 29.4	31
32	53.6	9.4 59.8	29.3 52.8	45.3 44.4	57.1 33.8	50.4 38.7	49.3 34.4	43.5 34.4	43.3 33.4	33.8 53.6	25.7 59.8	37.8 52.8	48.1 + 44.4	57.1 34.1	50.4 41.6	49.3 37.7	43.5 35.9	43.3 50.6	32
33	55.7	9.5 61.2	29.6 54.4	45.5 46.1	58.2 34.9	52.4 39.6	51.5 35.6	45.7 36.7	45.2 35.9	34.9 55.7	26.9 61.2	38.9 54.4	49.7 + 46.1	58.7 35.5	52.4 42.9	51.5 39.0	45.7 37.1	45.2 31.9	33
34	57.6	9.6 63.0	29.9 55.9	46.4 47.6	59.1 36.0	54.3 41.1	53.6 37.5	47.6 38.8	47.0 38.2	36.0 57.6	28.6 63.0	40.5 55.9	51.2 + 47.6	60.2 36.9	54.3 44.3	53.6 40.3	47.6 38.3	47.0 33.1	34
35	59.5	9.6 64.5	30.1 57.3	46.9 49.0	60.0 37.4	56.0 42.6	55.5 33.3	49.5 40.8	48.7 40.5	37.8 59.5	30.2 64.5	42.0 57.3	52.6 + 49.1	61.5 38.3	56.0 45.6	55.5 41.5	49.5 39.6	48.1 34.3	35
36	61.2	9.7 66.3	30.4 59.2	47.4 50.4	60.8 38.7	57.7 44.0	57.4 41.8	52.1 42.6	51.0 42.6	39.4 61.2	31.7 66.3	43.4 59.2	53.9 + 50.5	62.8 39.7	57.7 46.9	57.4 42.8	52.1 40.8	51.0 35.6	36
37	62.9	9.8 68.1	30.6 60.8	47.9 51.7	61.6 39.9	59.3 45.3	59.1 42.6	34.4 44.4	53.2 44.7	41.0 62.9	35.2 68.7	45.0 60.6	55.2 + 52.0	64.1 41.1	59.3 48.2	59.1 44.1	54.4 42.1	53.2 36.8	37
38	64.9	9.9 65.8	30.9 62.6	48.5 52.9	62.4 41.1	60.8 46.5	61.1 44.1	56.7 46.8	55.3 46.5	42.5 64.9	34.5 69.6	46.0 62.6	56.4 + 51.4	65.7 42.5	60.8 49.5	61.1 45.3	56.7 43.3	55.3 38.0	38
39	66.8	9.9 71.4	31.0 64.2	48.7 54.1	63.1 42.2	62.2 48.4	63.0 46.2	58.8 49.0	51.2 48.3	43.9 66.8	35.8 71.4	47.6 64.2	58.0 + 54.9	67.3 43.8	62.2 50.8	63.0 46.6	58.8 44.5	57.2 39.3	39
40	68.7	10.0 72.9	31.2 65.7	49.1 55.5	63.8 43.3	63.6 50.1	64.8 48.3	60.9 51.2	59.1 50.0	46.0 68.7	37.0 72.9	49.2 65.7	59.5 + 56.3	68.8 45.2	63.6 52.1	64.8 47.9	60.9 45.8	59.1 40.5	40
41	70.4	10.1 74.0	31.4 67.1	49.5 56.8	64.5 44.3	64.9 51.8	66.5 50.2	62.8 53.2	61.5 51.6	47.9 70.4	38.2 74.8	50.7 67.2	60.9 + 57.7	70.2 46.5	64.9 53.4	66.5 49.1	62.8 47.0	61.5 41.7	41
42	72.0	10.1 76.6	31.5 68.4	49.9 58.1	65.1 45.2	66.1 53.3	68.1 52.0	64.6 55.1	63.8 53.6	49.7 72.0	39.3 76.6	52.1 68.7	62.3 + 59.1	71.5 47.9	66.5 54.7	68.1 50.4	64.6 48.3	63.8 43.0	42
43	73.6	10.2 78.3	31.7 69.7	50.2 59.3	65.7 46.8	67.3 54.9	69.7 53.7	66.4 57.0	66.0 55.5	51.4 73.6	40.9 78.3	53.5 70.2	63.6 + 60.5	72.8 49.2	68.1 56.0	69.7 51.3	66.4 49.5	66.0 44.2	43
44	75.5	10.2 79.9	31.9 71.0	50.5 60.5	66.2 48.2	68.4 56.9	71.1 55.9	68.3 58.8	68.1 57.3	53.0 75.5	42.0 79.9	54.8 71.6	65.3 + 61.9	74.4 50.6	69.6 57.3	71.1 52.9	68.3 50.8	68.1 45.5	44
45	77.4	10.3 81.5	32.0 72.4	50.8 61.6	66.8 49.6	69.5 58.9	72.5 58.1	70.2 60.4	70.1 59.0	55.2 77.4	44.0 81.5	56.0 73.1	66.8 + 63.3	76.0 51.9	71.1 58.6	72.5 54.2	70.2 52.0	70.1 46.7	45
46	79.1	10.3 83.0	32.1 73.8	51.1 62.6	67.3 50.9	70.5 60.8	73.9 60.2	72.0 62.0	72.0 60.6	57.3 79.1	45.5 83.1	57.2 74.6	68.3 + 64.7	77.5 53.2	72.5 59.8	73.9 55.5	72.0 53.2	72.0 47.9	46
47	80.8	10.4 84.4	32.3 75.1	51.4 63.7	67.8 52.2	71.5 62.5	75.2 62.1	73.7 64.0	73.8 62.6	59.2 80.8	46.8 84.6	58.3 76.0	69.8 + 66.0	78.9 54.6	74.2 61.1	75.6 56.7	73.7 54.5	73.8 49.2	47
48	82.4	10.4 85.8	32.4 76.4	51.7 65.2	68.2 53.9	72.4 64.2	76.4 64.0	75.3 65.8	75.6 64.4	61.1 82.4	48.7 86.2	59.5 77.5	71.2 + 67.4	80.3 55.9	75.8 62.4	77.2 58.0	75.3 55.7	75.6 50.4	48
49	84.3	10.5 87.1	32.5 77.6	51.9 66.6	68.7 55.6	73.3 66.5	77.6 65.8	76.9 67.6	77.5 66.2	62.9 84.3	50.5 87.7	61.5 78.9	72.5 + 68.8	81.9 57.2	77.4 63.7	78.7 59.2	76.9 57.0	77.5 51.7	49
50	86.2	10.5 88.6	32.7 78.8	52.2 68.0	69.2 57.2	74.2 68.5	78.7 67.5	78.4 69.3	79.4 68.0	65.2 86.2	52.2 89.2	63.0 80.3	73.8 + 70.1	83.6 58.5	78.9 65.0	80.2 60.5	78.4 58.3	79.4 52.9	50

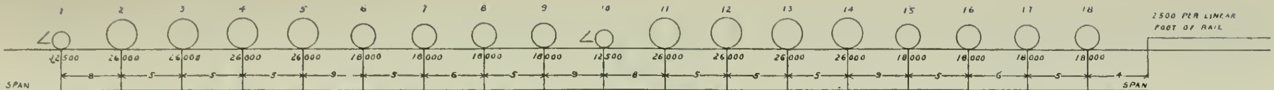
TABLE FOR TWO 1885 TONS ENGINES

Followed by 5000# per linear foot of track

Giving in thousands of pounds

END SHEAR UP TO 50 FOOT SPAN.

TABLE. I.



SPAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	SPAN
52	696	106 914	329 818	527 707	700 603	758 724	809 70.0	813 728	829 712	695 896	555 922	658+ 832	762+ 728	866 612	817 679	833 630	813 607	829 554	52
54	92.6	106 940	331 841	531 741	707 641	773 760	829 745	839 764	861 749	734 929	594 852	694+ 860	794 755	894 638	850 701	865 655	846 632	861 579	54
56	956	107 965	333 869	535 772	714 676	787 784	.847 77.9	86.4 798	89.1 78.3	77.1 861	631 981	727+ 888	824 762	92.0 664	880 726	895 68.1	877 65.7	89.1 604	56
58	987	108 990	335 899	539 806	721 713	80.0 829	864 81.4	886 832	91.9 81.8	808 993	67.0+ 1011	763 915	856 809	949 690	91.2 752	924 70.6	908 682	92.3 628	58
60	1018	108 1022	336 932	543 842	727 752	812 864	880 850	906 868	946 85.4	843 1025	71.0+ 1039	800 943	890 835	980 716	944 777	958 73.1	94.1 70.7	955 651	60
62	1046	109 1050	338 963	546 876	733 789	824 897	895 88.3	92.8 90.0	97.0 88.7	879 1056	748+ 1068	835 970	921 862	1009 742	97.5 803	988 756	97.1 73.2	98.5 678	62
64	1072	109 1064	33.9 1000	549 915	730 823	834 933	909 918	946 937	993 92.0	908 1086	784+ 1096	87.6 997	960 888	1045 768	1003 828	1022 78.1	1003 75.1	1018 703	64
66	1110	110 1116	341 1034	552 953	743 855	844 968	923 952	964 971	1015 952	938 1117	819+ 1124	915 1024	996 914	1078 794	1030 853	1053 806	1035 762	1050 728	66
68	1131	110 1150	342 1071	555 980	748 891	854 1000	935 98.5	980 1004	103.5 984	966 1146	854+ 1152	951 1051	1034 940	1113 820	1063 879	1083 831	1065 80.7	1080 753	68
70	1160	111 1186	343 1109	557 1021	75.5 924	863 1036	947 1021	996 1036	1054 101.5	992 1176	887+ 1160	985 1076	1073 967	1150 843	1094 904	111.1 856	1099 83.2	111.3 778	70
72	1195	111 1220	344 1145	560 1055	75.7 958	87.1 1069	958 1055	1011 1068	1072 1046	1017 1206	918+ 1208	1021+ 110.5	1110 993	1165 871	1126 929	114.1 862	1132 857	114.5 803	72
74	1227	11.1 125.9	345 1179	562 1069	761 999	87.9 1103	968 1088	102.5 1100	1089 107.7	1040 1235	948 1235	1054+ 1132	1145 1019	1225 897	1161 939	1173 907	116.1 88.2	116.5 828	74
76	1262	11.2 129.6	347 121.1	564 1121	76.5 1026	887 1136	97.8 1120	103.8 1131	1106 1108	1062 1264	976 1263	1086+ 1158	1180 1045	1263 922	1194 980	1204 952	1189 906	121.0 853	76
78	1298	11.2 1331	348 1247	566 115.7	768 1060	894 1171	98.8 1152	105.0 1162	112.1 1136	1083 1292	1002 1290	1117+ 1185	121.5 1071	1299 948	1231 1005	1239 95.7	122.0 93.1	124.1 878	78
80	133.2	11.2 1364	348 1280	568 1191	772 1094	901 1204	95.6 1184	106.2 1193	113.6 1168	1103 1321	1027 1317	1146+ 1211	1247 1096	1335 975	1267 1031	127.3 96.2	125.2 95.6	127.1 903	80
82	137.1	11.3 1398	349 1314	570 1223	775 1126	90.7 1236	100.5 1215	107.3 1223	1148 1198	1123 1349	1051 1344	1173+ 1237	1279 1122	1369 999	1305 1056	1308 1007	1282 981	1296 927	82
84	1408	11.3 1433	350 1349	572 1257	778 1162	913 126.8	101.3 124.5	1084 1254	116.3 1227	1141 1378	1074 1371	1199+ 1263	130.9 1148	1412 1024	1343 1081	1344 1032	1316 1006	133.2 952	84
86	1443	11.3 146.6	351 136.2	573 1291	781 1195	919 130.0	102.1 127.7	1094 128.3	117.5 1256	1158 1406	1096 1398	1224+ 1290	1336 1174	1435 1050	1380 1106	1379 1057	135.1 103.1	136.3 977	86
88	147.7	11.4 150.1	352 1415	575 1324	784 1228	925 133.1	1028 1308	1104 1313	118.7 128.5	1174 1434	111.1 1425	1248+ 1316	1364 1199	1466 1075	1415 1131	141.9 1082	1386 105.6	1394 1002	88
90	151.1	114 1535	353 1449	577 1359	786 1260	93.0 136.2	1035 133.8	1114 1343	1199 1314	1190 1461	1137 1451	127.1 1342	139.0+ 1225	1495 1101	1450 1157	145.6 1107	1423 108.1	143.1 1027	90
92	1546	114 1567	353 1482	578 1391	789 1292	935 1392	1042 1368	112.2 137.2	121.0 134.3	1205 1489	1156 1479	129.2 1367	1415+ 1251	1523 1126	148.5 1162	1492 1132	1458 1106	1465 1052	92
94	1579	114 1602	354 1516	580 1424	791 1324	940 1423	1048 1398	113.1 1401	1220 137.1	1220 1517	1174 1504	1313 1394	1438+ 1276	1550 1152	1528 1207	1526 1157	149.7 113.1	150.0 107.7	94
96	1614	115 1636	355 1550	581 1456	794 1355	945 1453	105.5 1428	1139 1430	123.0 140.0	1234 1544	119.1 1531	1333 1420	1461+ 1302	1576 1177	1550 1232	1562 1182	1534 1156	1536 1102	96
98	1648	115 1669	355 1583	582 1488	796 1386	949 1483	1061 1457	1147 1459	1240 1428	1247 1572	1208 1557	1352 1446	1483+ 1328	1601 1202	156.1 1257	1596 1207	1569 1181	1573 1127	98
100	1681	115 1704	356 1615	584 1519	798 1416	953 1513	1066 1486	1155 1487	1249 1456	1260 1599	1224 1584	1370 1472	1504+ 1353	1624 1228	1610 1282	1628 1253	1604 1206	161.1 1152	100
102	1716	115 1737	356 1647	585 1551	800 1448	958 1543	1072 1515	1162 151.6	1256 1484	127.2 1626	1239 1610	1388 1498	1524+ 1379	1647 1253	1638 1308	166.0 1258	1639 1231	164.7 1177	102
104	1750	115 1769	357 1679	586 1581	802 1476	962 1572	1077 1544	1169 1544	126.7 1512	1284 1653	1254 1636	1405 1523	1543+ 1404	1669+ 1278	1665 1333	1690 1283	1673 1256	1683 1202	104
106	1784	116 1802	357 1710	587 1613	804 1508	965 1601	1082 1573	117.6 1572	127.5 1540	1295 1680	1268 166.2	1421 1549	156.2 1430	1690+ 1304	1691 1358	1719 1308	1706 1281	171.7 1227	106
108	1818	116 1834	358 1742	588 1643	806 1538	969 1431	1067 1602	118.2 160.1	1283 1569	1306 1707	1282 1688	1437 1575	1580 1455	1711+ 1329	1717 1383	1747 1333	1738 1306	175.1 1252	108
110	1852	116 1866	358 1773	589 1674	808 1568	973 1660	1092 1630	1188 1629	1291 1595	1317 1734	1295 1715	1452 1601	1587 1481	1730+ 1354	1741 1408	1774 1358	1768 133.1	178.5 1277	110
112	1885	116 1897	359 1804	590 1704	810 1598	976 1688	1096 1659	1194 1651	1298 1623	1328 1761	1308 1741	1467 1626	1614 1506	1749+ 1380	1764 1433	1801 1383	1797 1356	181.7 1302	112
114	1917	116 1929	359 1834	591 1734	811 1627	979 1717	1100 1687	120.0 1684	1305 1650	1337 1787	1320 1767	1481 1652	1630 1531	1768+ 1405	1787 1458	1825 1408	1826 138.1	1848 1327	114
116	1950	116 1960	360 1865	592 1764	813 1657	983 1746	1105 1715	1206 1712	1312 1677	1346 1814	1332 1793	1495 1678	1645 1557	1785+ 1430	1809 1483	1849 1433	1853 1406	187.0 1352	116
118	1982	117 1991	360 1895	593 1793	815 1686	986 1774	1109 1743	121.1 1739	131.9 1705	135.5 1841	1344 1819	1508 1702	1660 1583	180.2 1455	1830+ 1509	187.3 1458	1888 1431	190.7 1377	118
120	201.4	117 2022	361 1926	594 1823	816 1715	989 1803	1113 1771	121.6 1767	132.5 1732	1364 1867	135.5 1845	1520 1729	1675 1608	1819 1481	1850+ 1534	1895 1483	1903 1456	193.5 1402	120
122	2045	117 2052	361 195.5	595 1852	818 1744	992 1831	1116 1799	122.1 1794	133.2 1759	1373 1894	1366 1870	153.3 175.5	1689 1633	1835 1506	1870+ 1559	191.7 1508	1930 1481	1962 142.7	122
124	2077	117 2082	361 1985	595 1881	819 1773	994 1859	1120 1827	1226 1822	1338 1786	1381 1920	1376 1896	1545 1780	1703 1658	1850 1531	188.9+ 1584	1940+ 1533	1953 1506	198.9 1452	124
126	2108	117 2113	362 2014	596 1911	820 1801	997 1887	1124 1854	123.1 1849	134.3 1813	1389 1946	1386 1922	1556 1806	171.6 1684	1865 1356	1907 1609	1959+ 1556	1977 1531	2014 1477	126
128	2139	117 2143	362 2044	597 1940	822 1830	100.0 191.5	1127 1862	1236 187.6	1349 1840	1397 1973	1396 1948	1567 1831	1728 1709	1879 1582	192.5 1634	197.9+ 1583	1999 1556	2039 1502	128
130	2170	117 2173	363 2073	598 1968	823 1859	100.2 1943	113.1 1909	1240 1903	1355 1867	1404 1999	1405 1974	1578 1651	1741 1734	1893 1607	1942 1659	1998+ 1608	202.1 1581	2063 1527	130
132	2201	117 2202	363 2102	598 1997	824 1887	100.5 197.1	1134 1937	1244 1930	1360 1894	1411 2026	1415 2000	1589 1882	175.3 1760	1907 1632	1959 1684	201.7+ 1633	2042 1606	2066 1552	132
134	2231	118 2232	363 2131	599 2026	825 1915	100.7 193.9	1137 1964	1249 1957	1365 1920	1418 2052	1423 2025	1599 1908	1764 1785	1920 165.7	1975 1709	203.5+ 1658	2062+ 1631	2108 157.6	134
136	2261	118 2261	363 2160	600 2054	827 1943	100.9 202.6	114.0 1991	1253 1984	1370 1947	1425 2078	1433 2051	1609 1933	1776 1810	1935 1682	1991 1734	205.2 1683	2082+ 1656	2130 1601	136
138	.2292	118 2[illegible]91	364 2189	600 2083	828 1971	101.2 2053	1143 2019	1257 2012	1375 1974	1432 2104	1440 2077	1618 1959	1786 1830	1945 1707	2006 1759	2069 1708	210.1+ 1681	2151 1626	138
140	2322	118 2320	364 2218	601 2111	829 1999	1014 208.1	1146 204.6	1260 203.8	1380 2000	1438 2131	1449 2103	1627 1984	1797 1861	195.7 173.3	2021 1785	208.6 1733	2120+ 1706	2173 1651	140
142	2352	118 2349	364 2246	602 2139	830 2027	1016 210.8	1149 207.3	1264 206.5	1384 2027	1445 2157	1456 2128	1637 2010	1807 1886	1969 1758	2036 1810	2102 1758	2138+ 1731	2192 167.6	142
144	2381	118 2378	365 2275	602 2167	831 2055	101.8 2135	1151 2100	1268 2092	1389 2053	1451 2183	1464 2154	1645 2035	1817 1911	1981 1783	2050 1835	2118 1783	2156+ 1756	2211+ 170.1	144
146	2411	118 2407	365 2303	603 2195	832 2083	1020 2163	1154 2127	1271 2118	1393 2080	1457 2209	1472 2180	1654 2060	1827 1937	1992 1808	2064 1860	2133 1808	2173 1781	223.0+ 172.6	146
148	2440	118 2436	365 2332	604 2223	833 2110	102.2 2190	115.7 2154	1275 2145	139.7 2106	1463 2235	1479 2205	1662 2086	1837 1962	2002 1833	2077 1885	2148 1833	2190 1806	2248+ 1751	148
150	2470	118 2464	366 2360	604 2251	834 2138	1024 221.7	1159 2181	127.8 2172	1401 2133	1466 2261	1486 2231	1670 2111	1846 1987	2013 1858	2090 1910	216.2 1858	2206 1831	2266+ 177.6	150

TABLE FOR TWO 1885 TONS ENGINES

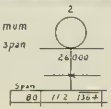
Followed by 5000* per linear foot of track

Giving in thousands of pounds

END SHEAR FOR 52 TO 150 FOOT SPANS

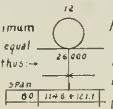
TABLE 2.

Position of maximum reaction for one span shown thus →



136,400
26,000
162,400 = reaction

Position of maximum reaction for two equal successive spans, thus:→



114,600
121,100
26,000
261,700 = reaction

Also position of maximum moment at center of span of double lenght. Maximun moment = Reaction$\left(\frac{\text{span}}{4}\right)$

M M (160 span) = $\frac{261{,}700 \times 160}{4}$ = 10468000 mum moment at the first panel point then is 162,800 times 72, times 18, divided by 90, which equals 2,344,300 foot pounds.

For maximum moment at second panel point a 36-foot span is compared with a 54-foot span. Thus a 54-foot span to the left of wheel 13 gives 79,400 and a 36-foot span to the right gives 50,500 and a wheel load of 26,000, which is a total of 155,900 pounds. The maximum moment at the second panel point is 155,900 times 54, times 36, divided by 90, which equals 3,367,400 foot pounds.

The maximum shear at the panel point is now to be considered. The concentration at this point for the loads in the panel to the left and on the remainder of the span to the right is found. Also the concentration at each panel point to the left for loads in their adjacent panels. The difference is then found between the moment of the first-found concentration around the right hand end of the span and the moment of the other concentrations around the left hand end. The difference thus found divided by the span length is the shear. The shear is a maximum when the difference is maximum.

There will be no concentration on the span to the left when the first panel point is considered and so the shear is maximum when the concentration at the point is maximum. In this case then the position is the same as for maximum moment. Thus at the first panel point of our 90-foot girder the concentration was found to be 162,800. The shear is then 162,800 times 72, divided by 90, equals 130,200.

For shear at second panel point let us try wheel 3. The concentration between an 18-foot span and a 54-foot span is 22,300, plus 84,100, plus 26,000, equals 132,400. The reaction at first panel point is 16,300. The moment of 132,400 around the right end and 16,300 around the left end and the result divided by 90 is 76,200, which is the shear. If wheel 2 or 4 was compared we would find wheel 3 gave the maximum. We do not compare any other wheels because the concentration at the panel point would be smaller and the concentration to the left would be larger.

The examples used in this paper were taken at random. The same problems were calculated by wheel loads but not referring to the tables and the results compare with the results as given by the table. The greatest difference was found in the moment of the 18-foot stringers which was one-third of 1 per cent too large. The average difference in results was one-thirteenth of 1 per cent.

It will be observed that the dead load can be added into any of these calculations and can be more nearly obtained by having the live load. The bridge engineer can vary the tables as he sees best, by calculating fewer spans or by carrying the tables further.

The time to calculate and tabulate Table 1 took the author less than 32 hours by actual count, and Table 2 about 40 hours. Engine diagrams having wheel loads in fractions of thousands and distance between loads in fractions of feet, will vary the work and time to calculate.

DISCUSSION.

Mr. Parkhurst—I would like to ask Mr. Gibson if, in his estimation, it is desirable to work out detailed tables of this kind for a very large number of engines, or whether in actual practice it is not enough to use the distributed weights of one heavy engine to prepare such a table and do the other work in perhaps some less cumbersome way?

Mr. Gibson—I would not advise the calculation of such a table for very many engines, but I can give an illustration. A heavy engine will give a large moment on a long span. I do not think I am giving anything away when I state that one of the railroads entering Chicago thought they would try to run all the engines over their standard pile bridge to see which would give the heaviest moment. They commenced with the heaviest engine and ran down the list until they got to a little switch engine which was tenth in their list. That gave a larger moment than any of the other engines. Had there been a diagram like this for each engine you could have seen at a glance that the switch engine would give a larger moment.

Mr. Parkhurst—The refinement of calculating out a table of this kind for small fractions of a foot, rather than having them in general terms, was more what I alluded to. In figuring out a lot of bridge stresses for different styles of engines our experience has been that we have such an immense variety of engines that to make calculations for one of every kind would keep a large office force busy a good deal of the time. We have thought it sufficient to take certain typical engines and make detailed calculations for their loading, and judge of other engines by comparison on common grounds, rather than on minute fractions and figures. I presume the experience of other roads is very similar.

You will remember that this paper compares in a general way with one presented a few weeks ago—by a fellow member, Mr. Sanne.*

Mr. Gibson—Mr. Sanne's paper illustrated a graphical method of finding stresses. I believe he stated you could find the position of maximum moment by judgment—picking out the wheel you thought would give the largest moment, and finding out what the maximum would be from that. Or, after trying this wheel, if you thought another wheel would give a greater moment, try that. You notice that in the table here presented the wheel that will give the maximum moment is indicated by a plus sign. You find that position by adding the two reactions and the wheel load together. Wherever this concentration is a maximum, then the moment will be the maximum. Mr. Sanne did give a table that showed the wheel reaction from one wheel for spans in each direction, which would be equivalent to one column of this table. However, he did not go into the finding of moments or shears from such a table.

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* JOURNAL, Feb., 1904, VIII, p. 34.

Mr. Parkhurst—In listening to Mr. Linday's paper there was one point that came to mind, and that was, if I remember the statement correctly, that it was very rare that the four points of support were in the same plane, and the statement, if I got the right impression, was intended to carry the idea that rigidity of the truss would be enough to cause possibly one of those points to bear with a great deal less load than it should on the masonry or the support, whatever it might be. Am I right?

Mr. Linday—Yes, that was the idea.

Mr. Parkhurst—You would not say that of the truss span, would you?

Mr. Linday—I would, if it had very substantial bracing. If the floor is riveted solidly to the posts, and the stringers likewise to the floor beams, so that there is a rigid structure throughout, then if it should happen that the masonry under one corner settled more than at the other corners you would have a case where two diagonal corners would bear more than two other corners.

Mr. Parkhurst—I have in mind a case where a solid floor bridge was built over another railroad and supported on heavy masonry abutments. The bridge was on a tangent, but the curve began on an embankment 200 or 300 feet from the end of the bridge, and it became desirable to give a greater elevation. The bridge was jacked up and the easterly end of the bridge was tilted, and it was expected that we would have trouble with the other end. However, we did not meet any trouble of that kind at all. The floor was very heavily bracketed to the posts, fastened to web plates in the usual way, everything being square and riveted up very snugly indeed.

Mr. Linday—This was just an attempt to explain how the rollers might get skewed. In most cases there are at least ten tons on the roller rests, but nevertheless they do get skewed. Ten tons is a considerable pressure and they cannot get skewed unless the pressure is diminished considerably. I remember a case of a 150-foot span with small rollers where this movement had taken place.

Mr. Parkhurst—Were those rollers held in place?

Mr. Linday—I cannot say as to that. The case I mentioned was a bridge over the Mississippi River near Clinton. I went down and looked at it and saw that it was skewed. I do not suppose anybody knows the exact reason.

Mr. Parkhurst—We have found in some cases that the sand has a trick of blowing in to the nest of rollers, and that sand will get under the rollers and act as a wedge, and very funny things wlll happen.

Mr. Linday—It might happen also that the pier would settle more in one end than the other. Then you would have less pressure there.

Mr. Parkhurst—One thing occurred to me in reading Mr. Gibson's paper. I think it would have been better if more explanations had been given in figuring out the tables. He says in one case, "any span can be divided into two equal and unequal parts." By this he means that the span is supposed to be cut off at that point, then he figures his reaction as given here. That was very hard to understand in the paper. That is the idea, is it not?

Mr. Gibson—The bending moment at any point in the span is the amount of reaction you would get on a pier at that point. That is what causes your bending moment at any point and what you must take care of. Therefore, your bending moment is the same as if you put a load at that point and figured it for that concentrated load.

There is one thing I might add about figuring a table like this. It is not so hard if you go about it in the right way. Do not calculate loads for different wheels for each span, but go down a column. Begin at one wheel and find the moment for each span and then calculate the reactions right down the column. I have culculated in table 2 a column in an hour and tabulated it. I carry along with me a system of checks. I figure the moment at every wheel load; that gives it for every 5, 6 or 10 feet and when passing any of these wheels see if my moment is the same, which gives a check on the work. Then the way I checked my table was to figure the last span for each wheel. I have used these tables quite a little and they have only been checked in my calculating, yet in 30 problems which I calculated for the shear in the span itself, I have found that the average result was $\frac{1}{50}$ of 1 per cent variation only. So it shows that the tables are practically correct.

Mr. Parkhurst—Is it not a fact that in most tables you find there is a certain law of increment that governs the increase or decrease in the results either across the line, or up and down?

Mr. Gibson—You will find that true in table 2. The longer the span, the more nearly equal will the load average. However, each result in the table was found by calculation.

Mr. Garrett Davis—What percentage for impact was allowed?

Mr. Gibson—There was no impact allowed in the table, and the percentage would have to be determined on the allowed percentage by the railroad.

Mr. Davis—Is there any uniform practice as to the percentage for impact?

Mr. Gibson—I do not think there is any uniform method of figuring it from some fixed per cent.

Mr. Davis—Cooper's specifications take care of impact by using a low stress per square inch. I suppose the only way to figure it is to take the deflection into account. If there is no deflection, there is no impact. I would like to know what is customary or what is the usual percentage to allow for impact.

Mr. Linday—If you refer to the American Bridge Company's specifications, I think you will find the best method in them.

Mr. Parkhurst—The specifications made by Mr. C. C. Schneider, formerly of the American Bridge Co., contained a very extensive discussion of that, and carried it all out.

I have been in the habit of making different allowances on account of different cases.

Mr. Gibson—One formula is 40 per cent minus four times the square root of the length of load producing the impact. That is, if you have a 100-foot span or more, the square root of it would be 10 per cent; four times that would be 40 per cent, and you would allow no impact on anything over 100-foot span. You allow a percentage under that according to your span, up to 40 per cent. I do not quite agree with that formula, because I think a short span—say an 18-foot stringer in a long span—need not be figured as high for impact as if it came in a shorter span. I think impact should be considered for deflection, and where there is no deflection, the impact should be high. But where the stringer or floor beam occurs in a long span, the deflection on a span will help to take up the impact due to the suddenness of the load, and therefore need not be considered as high in a shorter span.

THE USE OF PULVERIZED COAL FOR FUEL UNDER STEAM BOILERS.

J. M. Sweeney, M. W. S. E.

Read March 2, 1904.

At the time a promise was made to prepare a paper on this subject for presentation before the Society, it was anticipated that before the date at which the paper was to appear would be reached, further data would be forthcoming. In this hope, however, the writer has been disappointed, and begs therefore, to apologize for the incompleteness of the paper, hoping merely that it may bring out some discussion and statement of experiences of members who have had greater opportunities to note more closely what has been accomplished and what have been the drawbacks to this form of combustion.

The writer's attention was first directed to this subject about 1889 when Erastus Wiman, then particularly active as a promoter in new departures, called attention to the possible economy to be effected by the use of fuel in a powdered form. It is sufficient to say that so far as the writer knows the undertakings at that time with which Mr. Wiman was connected were unsatisfactory in their results, and that a part of this result was chargeable to the high cost of pulverization.

Of recent years, and particularly with the progress of the manufacture of cement pulverizing machines, methods have been so perfected that it may be safely stated that pulverization of most coals, particularly when dried, can be secured within a cost of 10 cents per ton.

At the present time the methods being experimented upon for the use of pulverized coal as fuel under steam boilers seem to be divided into two classes: One where the material is pulverized in a detached pulverizing plant and the product conveyed to hoppers over feeding machines in front of the boiler, and the other where an independent pulverizing machine is used and discharges its product immediately into the combustion chamber.

As a sub-division of the class first named there seems to be two methods: One where the pulverized coal is fed into a combustion chamber by the use of a circular brush usually made of steel bristles, and the other where material is fed in by a blast of air or steam. So far as the evaporative economy of these methods is concerned there seems to be but little choice, and advocates who have had experience may be found with preferences for both plans.

In this paper it is thought best to confine the matter entirely to the mechanical operation and to avoid any statements in reference to chemical results, except so far as evaporation may be noted. Again, it is fair to say that the only substantial data which is available to the writer applies to the brush type of machine, Fig. 1, for feeding.

The following table of evaporations secured will give a very fair idea of what may be expected in the way of such results from fuels prepared in this way:

	I.	II.
Water evaporated from 196° and 194° cu. ft.	639	886.2
Fuel burned, lbs.	4205	5894
Steam pressure, lbs.	125	130
Factor of evaporation	1.06	1.06
Water evaporated from and at 212°, lbs.	40756	56569
Fuel burned, lbs.	4205	5894
Lbs. of water evaporated from and at 212° per lb. fuel	9.7	9.6
H. P. developed	1182	1640
H. P. units per hour		272
Lbs. coal per H. P. developed	3.5	3.59

The analysis of fuel in the first column is not known. That of the second table is as follows:

Fixed carbon	54.70
Volatile matter	34.80
Ash, sulphur and moisture	10.50
	100.00

Of coals used in some trial runs and compared to hand firing the gain in the use of the coal pulverized as compared to hand fired was as follows:

GAIN.

No. 1. Evaporation per fuel, 25 per cent.
Evaporation per combustible, 24½ per cent.
Pounds fuel per H. P. units developed, 21½ per cent.
Pounds combustible per H. P. units developed 21 per cent.

No. 2. Evaporation per fuel, 12 per cent.
Evaporation per combustible, 12 per cent.
Pounds fuel per H. P. units developed, 12.6 per cent.
Pounds combustible per H. P. units developed, 13 per cent.

As deduced from the following data:

No. 1.	Pulverized.	Hand Fired.
Water evaporated from 198°.....	2656.5 cu. ft.	3258.15 cu. ft.
Fuel burned..................	18040 lbs.	27568
Combustible burned (see Anal.)..	16146 lbs.	24674
Steam pressure...............	129 lbs.	126 lbs.
Chimney draught..............	$\frac{5}{16}$-in. water col.	⅜ "
Stack temperature............	490°	580°
Factor of evaporation.........	1.06	1.06
No. 2.		
Water evaporated from and at 212°......................	169262 lbs.	207633 lbs.
Fuel burned..................	18040 lbs.	27566 lbs.
Combustible burned...........	16146 lbs.	24674 lbs.
Water evaporated per lb. of fuel from and at 212°...........	9.4	7.5
Water evap. per lb. combustible from and at 212°...........	10.47	8.4
H. P. units developed..........	4907	6018
H. P. units developed per hour..	204	250
Lbs. of fuel per H. P. developed..	3.6	4.58
Lbs. of combustible per H. P. developed	3.2	4.1

Again the following scattered data has been accumulated, which furnishes some information on these results:

Hours duration.	Cubic feet of water evaporated.	Pounds water evaporated.	Feed water temperature. Degrees F.	Steam pressure—Pounds.	Coal Consumed.	Factor of Evaporation.	Pounds of water evaporated per pound of fuel—actual.	Pounds of water evaporated per pound of fuel, from and at 212 degrees F.	Horse power developed.	Horse power developed per hour.	Pounds of fuel per horse power developed.	Pounds of water evaporated from and at 212 degrees per pound. Combustible, per analysis.*
4	351	21,278	177	114.7	3,531	1.079	6.03	6.50	665	166	5.30	6.98
4	430	25,980	185.6	116.5	2,855	1.071	9.01	9.75	807	202	3.54	10.47
4	440	26,642	180	114	3,008	1.076	8.86	9.53	822	205½	3.67	10.23
4	423	25,821	179	112.7	3,110	1.077	8.30	8.94	806	201½	3.85	9.64
4	429	26,006	177	111	2,690	1.078	9.67	10.42	812	203	3.31	11.19
4	420	25,544	167.6	114	2,691	1.089	9.49	10.33	807	201¾	3.33	11.09
4	431	26,136	176	113.9	2,806	1.08	9.32	10.06	818	204½	3.43	10.80
2½	235	14,286	169	116	1,416	1.087	10.09	10.97	450	180	3.37	11.78
5	284	17,117	192	103 8	1,949	1.061	8.78	9.32	526	105	3.70	10
5	240	14,640	159	100	1,897	1.095	7.72	8.45	464	93	4.10	9.07
11	776	47,103	172	109.03	5,274	1.082	8.93	9.66	1,477	134	3.57	9.59
11	687	42,030	149.5	101.5	4,940	1.105	8 50	9.39	1,346	122	3.66	9.12
7	337	20,557	159	115	2,406	1.098	8.54	9.38	654	93½	3.68	9.17
Total, 69½ hours, 333,140.							Averages, 9.44			150½	3.69	9.93
	a 119	7,325	130.4	115	1,193	1.127	6.14	6.92	240	190	4.97	7.43
	b 195	11,807	180	109.7	1,141	1.076	10.35	11.13	368	184	3.10	11.92
	c 284	17,164	185.5	117	2,935	1.071	5.85	6.26	530	265	5.53	6.72

a 2:40 to 5 p. m. b 5 to 7 p. m. c 7 to 9 p. m. **Fires were started at these times with boilers cold, having been without fires in each case not less than 16 hours. During and at the finish of this run the total of ash and clinkers removed was 1,828 lbs., being 4.7 per cent of the total amount of fuel burned. The last three were special experimental runs.

From these results it will be readily seen that the combustion of fuel in this form promises some economy, and it is fair to say that so far as the writer has ever examined the operation of any of these plants they promised fair results in the way of combustion without smoke.

In some cases, however, the promises made concerning results to be obtained from the use of fuel in pulverized form, are perhaps as ludicrous as any which may be found based upon hope and great expectations rather than that which is accomplished.

The following quotation from a catalogue of one of the numerous companies promoting apparatus of this character, is interesting if true. Referring to locomotive work they say: "This system is admirably adapted to locomotive work. There will be avoided the present loss of solid fuel through the exhaust force of steam; there will be no smoke or cinders in the fire box; the exhaust steam now used to create the required draft in the fire box would under this system be utilized in heating feed water of boiler. *In practice this makes a condensing engine of the locomotive.*" (The italics do not appear in the original text).

The next stage in the undertaking in the use of pulverized coal for fuel under steam boilers concerns the form of furnace best adapted to the economic combustion of the fuel in this form. We have seen in the foregoing tables practically the extent of the side of the operation which is to be counted as gain, and if the cost could be halted at the cost of the pulverization, it would be simplified and no questions arise as to the real economy of the operation. It is however, really at this point that most of the troubles begin. In the use of the method first referred to where the pulverization is accomplished in a detached machine situated away from the feeding device, the handling and conveying of the pulverized coal in order to place it in the hopper of the stoker is by no means an easy problem, and so far as the writer knows has not been accomplished in a manner satisfactory to the user. The usual plan is through the medium of screw conveyors, or similar means, operating overhead and depending on the gravity of the pulverized fuel to descend from the conveying trough into the hopper of the stoker. Under these conditions great fluctuation occurs in the constancy of the feed supply and is affected by the humidity of the atmosphere, since the material has an affinity for moisture, causing its rapid absorption, and a resultant stoppage and caking at times in the masses.

The usual practice has been after pulverizing the material, and in the cases of the brush stoker to a fineness of about 100 mesh, to elevate it into a large hopper or tank, this tank feeding into an overhead conveyor, and the material running by gravity from the

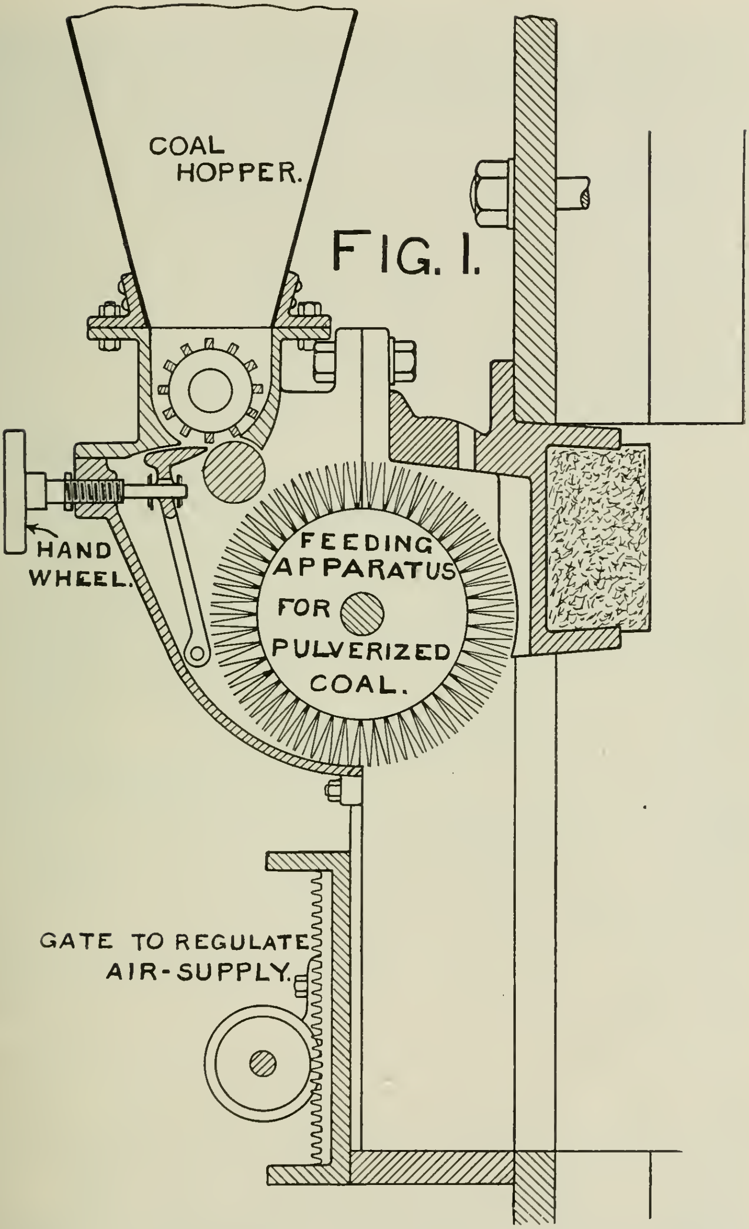

COAL HOPPER.
HAND WHEEL.
FEEDING APPARATUS FOR PULVERIZED COAL.
GATE TO REGULATE AIR-SUPPLY.

FIG. I.

tank into the conveyor trough. This method practically encounters the caking over of the material in arches in the large hopper and a resultant failure to flow properly into the overhead conveying mechanism.

The fine coal dust finds its way through the slightest openings in any of the retaining parts, and unless the whole of the mechanism employed for this purpose be practically steam tight, the boiler room is soon covered with black coal dust, and this fact notwithstanding the statement of one of the companies which says: "By its use the boiler house can be kept as clean as the engine room."

So far as these plants have been installed to the knowledge of the writer, it would require more than the economies effected in combustion to offset the very objectionable dirt and trouble which follow the elevation of the material overhead, and seemingly better results might be obtained if the pulverized fuel were not raised any higher than its point of combustion in the furnace. This troublesome feature is to a large extent avoided in the second classification of machines which pulverize and discharge the product immediately into the combustion chamber, but in the record of such machines some accidents have followed their use, which has in some cases been attributed to an explosive mixture formed by the air and powdered coal before it is delivered into the combustion chamber.

This condition the advocates of the first method, that of the brush stoker, claim to avoid. But passing by these annoyances as perhaps surmountable in some way yet to be devised, we come to the consideration of the form of furnace itself, and in most cases so far as the boiler settings go, they approach the methods shown in Fig. 2, of furnace construction under a water tube type of boiler.

Relating again to the brush method and to Fig. 1: Situated under the brush and in the lower part of the frame carrying the screw mechanism, is a gate which is operated through the rack and pinion shown. This gate regulates the supply of air which goes into the combustion chamber and is mixed with the pulverized fuel after it has left the brush and been projected into the combustion chamber. This combustion chamber is merely a tunnel about 18 inches wide by some 14 inches high in the middle of the low sprung arch making its crown. This tunnel is paved with two layers of fire brick and is similar in construction to most of the close joint settings used under boilers.

So far however, this construction has been most unsatisfactory, since it seems to concentrate the combustion into a small zone of fusion which expends itself in the melting of the brick exactly as a blow pipe might be expected to do, rather than in the dissemination of heat units through the absorbing surface of the boiler. This action has resulted in the undoing of the economies found from tests over short runs, where the action has been distributed over a measurable period of practical utility.

An interesting installation is now about to be made by one of the most persistent experimenters along this line, who has found that with the furnace construction just described the costs of maintenance and operation largely overbalanced any gains. They are inaugurating a water jacketed combustion chamber, or rather two of these chambers applied to each standard 72-inch return tubular

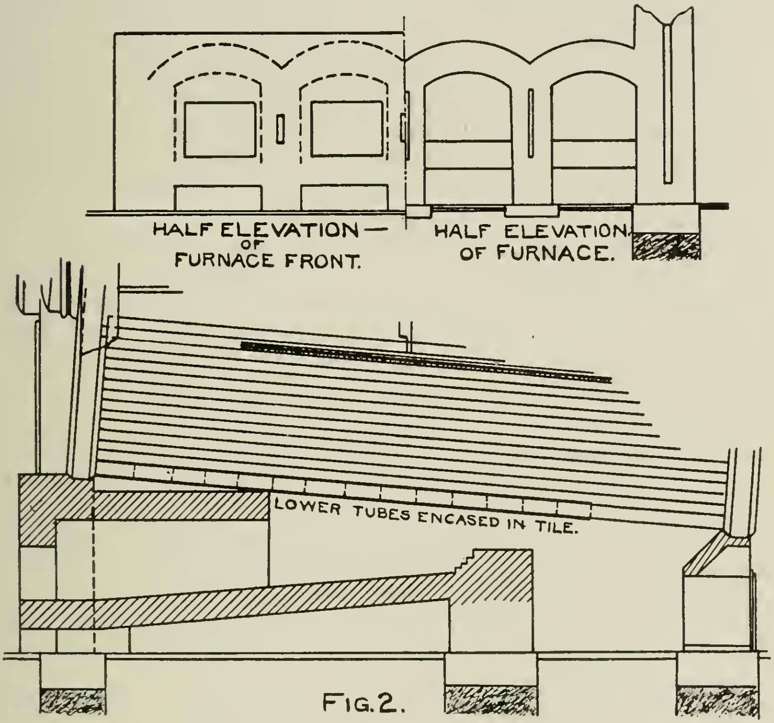

HALF ELEVATION — OF FURNACE FRONT.
HALF ELEVATION OF FURNACE.
LOWER TUBES ENCASED IN TILE.

FIG. 2.

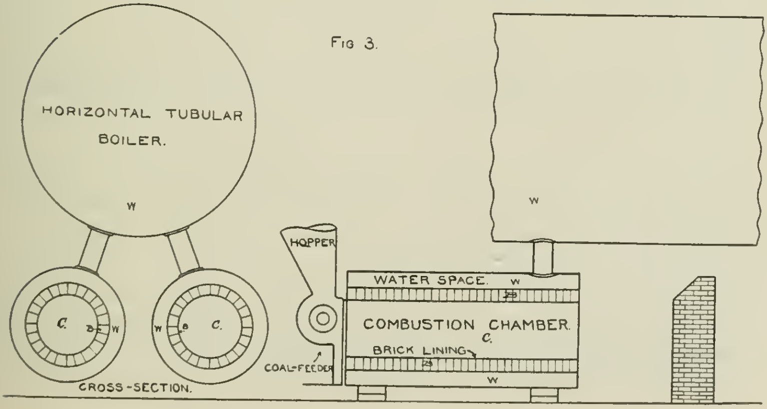


FIG 3.

boiler, these chambers lying under the main shell of the boiler and being brick lined; the water jacket of the combustion chamber being connected directly to the shell of the boiler with the hope of securing a satisfactory circulation. This arrangement will be readily understood by reference to the acompanying sketches, Fig. 3, where W is the water space of the boiler and combustion chamber, B the brick lining, and C the combustion chamber as shown.

In the case of the flat floor described under the combustion arch of the setting shown in Fig. 2, rapid deterioration of the floor has been encountered from the deposit of slag, or what it may be, occuring there in the use of most soft coals. This deterioration at times has been very rapid and destroyed the bottom of the combustion chamber in some cases after 48 hours of use.

In the arrangement shown in Fig. 2, the repair of this floor and of the crown, which sometimes has been a close second to the floor in its deterioration, has caused a great deal of preparatory work and practically the entire rebuilding of the combustion chamber. It is hoped to avoid this in the plan shown in Fig. 3, or at least to so readily repair the wear, that no annoying disuse of the boiler will be encountered.

When bituminous coal is pulverized for purposes of use in installations of this character, the non-combustible in the coal is pulverized as a part of the mass, and when fed into the combustion chamber, this non-combustible must go somewhere, and seems to be generally deposited back of the bridge wall, or in the flues or between the flues, or upon the tops of the baffle plates, thus requiring very frequent cleaning of these parts of the furnace and boiler, usually developing a loss in evaporative results as these cleaning periods are left behind.

Within the knowledge of the writer no installation of this method of firing steam boilers has continued to be used for any appreciable period after its installation, but has been abandoned on various excuses.

Pulverized coal has been and is being successfully used in many cement mills for use in the rotary kilns, but here the by-products of the combustion pass off with the clinker and go to swell the volume of cement.

The most successful attempt examined into is in the plant of a company producing malleable iron, where fuel in this form is used for the annealing furnaces, and also under the boilers. The installation is a sub-division of the first-class, that of a steam jet and an air blast combined for the feeding of the fuel. Fairly satisfactory results are obtained in the annealing ovens, and the system has been continuously used for about three years.

In the application under the boilers which are of the standard externally fired return tube type, a very large combustion chamber is used, covering the whole of the space from the bottom of the boiler to what would be the bottom of the ash pit in the ordinary setting, and of a width somewhat in excess of the diameter of the boiler shell, the length being about equal to the usual length of grate bar, an arch being turned from side wall to side wall, the crown of the arch against the bottom of the boiler in order to protect the shell from the very intense heat in this large combustion chamber. Here much of the blow pipe effect resulting from the setting as shown in Fig. 2 is lost, but after several years' trial under the boilers at this establishment, it is conceded that the excess cost of the furnace maintenance, over-balances the economies resulting from this form of combustion.

DISCUSSION.

Mr. Parkhurst—The Illinois Central Railroad Company has been making some experiments on using pulverized coal for fuel, and if there is anyone here who knows anything about this matter, we would like to hear about it.

Mr. Schaefer—I would like to ask Mr. Sweeney if he has ever known of a plant operating successfully?

Mr. Sweeney—In my paper I make the statement that I do not know of any plant of that kind which has continued in operation with any degree of success. The plants have generally been abandoned. The only exception I know of is a malleable iron works, where for some time they used this method under the boilers with this large combustion chamber.

Mr. Schaefer—How long, several months?

Mr. Sweeney—Over a year. In conversing with a friend of mine the other day, in speaking of this plant he said he called at one time, and after some objection on the people, had been allowed to see it. However, before allowing him to see it, considerable time was spent in preparing it for his inspection. The gentleman I speak of is here to-night, and has had very much more experience than I along these lines. I have approached this subject from the standpoint of the "doubting Thomas." I do not mean to say this cannot be accomplished, as that is too much to say, when we remember that someone predicted, long ago, that a steamship could not cross the ocean because it could not carry enough fuel.

Mr. Chas. E. Sargent—It seems to me that this lack of discussion is not because there is not a due appreciation of the paper, but because Mr. Sweeney has so thoroughly settled the question that there is nothing to discuss.

From the author's experience, as well as the experience of many others who have tried the pulverized fuel proposition, they are no doubt satisfied that though using the best apparatus now obtainable, the scheme is not yet a success; furthermore, those whose business it is to utilize all the possible heat that is in the coal, are drifting away from the present practice of burning the fuel under a boiler to generate steam, and the possibilities are that as there can be no urgent demand for the apparatus the powdered fuel scheme will never become a commercial success.

We know that the reciprocating steam engine has attained as high an efficiency as ever the most enthusiastic engineers can expect, and we must look to other prime movers if we desire to deliver more work with the same fuel.

The internal combustion engine is one of the prime movers of the future, and in order to prepare the gas for the same, the coal in large chunks or small, dirty or clean, is shoveled into the producer, and for which very much less skill is required than in firing a boiler. Eighty per cent of the heat of the fuel is converted into gas, which gives a very high efficiency when burned in the gas engine cylinder.

A pound of ordinary coal used in this way will easily furnish a brake horse power hour. An internal combustion engine will deliver a boiler horse power on 10,000 B. T. U.'s from a pound of coal.

For this reason it appears to me that pulverized coal for power purposes has no future, even if it has advantages over the present methods of firing.

Mr. R. F. Massa—I happened to come in contact with tests made some little time ago of a pulverizer which blew the coal into the boiler immediately after it was pulverized, and those tests showed that it took 10 per cent of the steam to operate the pulverizer. I would like to ask what the method of pulverizing is by which they are able to pulverize coal for 10 cents per ton? The reason I ask this is, that in one plant I know of, the price was very much more than that—in fact, seven or eight times greater. That is, taking the coal from the car and delivering it to the boiler ready to burn.

In regard to the ash, I think it is possible to get much better results in a vertical than in a horizontal boiler, where you have the deposit on the tubes and baffle plates.

Mr. Sweeney—In regard to the price for pulverizing, I understand that the 10 cents per ton covers the cost of pulverizing the coal, including the power and the wear and tear of the machinery. I do not think that price takes into account the handling of the coal. The type of pulverizer is that of the Huntington mill. There are two or three well known types of that form of pulverizer.

The President referred to the Illinois Central plant; in that installation they use what is known as the Clark mill. I understand that in their experiments, which extended over a period of six or eight months, that, without a drying machine, the cost of coal, so far as pulverizing is concerned, did not exceed 10 cents per ton. I do not know anything about the cost of handling.

I cannot answer the question as to the quantity of air which gives the best combustion, or distribution at various periods. After the furnace is heated up, the operation of a plant is supposed to be continuous. It ought to be maintained at the maximum rate of combustion.

The annealing furnaces in which this fuel was used had formerly been operated with oil, and seemingly the continued use of the pulverized coal in the furnaces would justify the claim that was made by the experimenters that it was a paying change. I have never been able to get any comparative statements that were tangible.

Mr. Schaefer—I believe, with Mr. Sweeney and Mr. Sargent, that pulverized coal will hardly come into general use, and with Mr. Sargent that long before we come to that point we will convert it into gas and so burn it. I am quite familiar with the methods in use in cement plants, and believe coal can easily be pulverized for 10 cents, aside from unloading from cars. It is either done with the Huntington, Griffin, or, more largely lately, with Tube mills, whereby they grind it very fine.

There are a number of reasons why I do not think pulverized coal will come into use—one is, its explosive character. On this account it is quite common to isolate the plant. At a plant at Sandusky, Ohio, a fire started in their grinding room and burned that part of the plant. No one knew what caused the fire.

The principal thing I wanted to mention was a very interesting case which came under my observation a couple of years ago, an explanation of which might be useful in preventing someone here to-night from pursuing the same course.

About two years ago there was built a large cement plant near St. Louis by the St. Louis Portland Cement Company. When they designed that plant it so happened that their coal grinding plant was in such a position between the cement burning room and the boiler house, that they could easily, by enlarging their coal grinding capacity, arrange it so they would have enough powdered coal to use under the boilers, also their manager thought they would need a double unit for grinding—one for a relay and one to be used for grinding the coal. The boilers were the Babcock & Wilcox type. They made a long combustion chamber about like that shown on page 147, Fig. 2, except that it was in front of the boilers. It was 10 or 12 feet long—a very long chamber, and arched over. The coal was blown into the front. It did not take over 48 hours to develop troubles, and they were serious. These came in a very unexpected way. A slag formed which, while it was hot, would run, but after a while it built up so high that they had to let the chamber cool off and pick it out with picks. It was a black glassy slag; not only that, but soot formed on the flues in such a way as to make serious trouble. As soon as they could get to it, they tore out this apparatus and hand fired the boilers.

Mr. W. L. Abbott—If it were feasible to burn powdered coal under a boiler, I still have doubts that it would be practical to use the system on account of the difficulties in grinding, particularly in a large plant where several hundred tons of coal are burned during, say, 24 hours. The apparatus and space necessary for grinding machinery, and the facilities for storing, would be a serious matter. Furthermore, I do not believe that the machine has been built that will grind uniformly and rapidly all kinds of coal, whether wet, dry or frozen.

Mr. Schaefer speaks of the danger of an explosion in case the coal is stored, and the necessity for grinding and using at once, with no storage.

I would not condemn the system altogether on the statement of a gas engine man. These people get so in the habit of running down a steam plant that they can never get up and make a speech on any subject without saying *delenda est Carthago.*

Mr. E. H. Stroud—I have some information of what is being done in England and on the continent of Europe to-day with powdered coal as fuel for steam boilers which may cast a new light upon the subject, especially as I am able to state authoritatively that 75 per cent to 80 per cent of the heat units of the coal are being given to the water for the making of steam in daily practice and that 80 per cent efficiency has been slightly exceeded on some occasions. I can also say that the combustion chamber used lasts for 60 days without repairs, which is as long as or longer than any boiler should be allowed to run without cleaning, and when repairs have to be made they cost no more than is now spent for the renewal of grate bars, fire brick, etc.; whereas hitherto the rapid deterioration of the combustion chamber has been one of the most serious and expensive defects of this method of burning coal.

This successful application of powdered coal as fuel for steam boilers, is what is known as the "Cyclone" system. Amongst the English installations are 345 Cable street, London; the South Staffordshire Steel & Ingot Works of Messrs. Hickman, Ltd., at Bilston; and the Navy Yard at Portsmouth.

It is claimed for this system that it has been brought to a practically and commercially successful point by grinding the coal to great fineness at a low cost, and by obtaining thorough and automatic admixture of air with the powdered coal, with absolute regularity of feed, thus obtaining entire combustion of the carbon with complete absence of smoke.

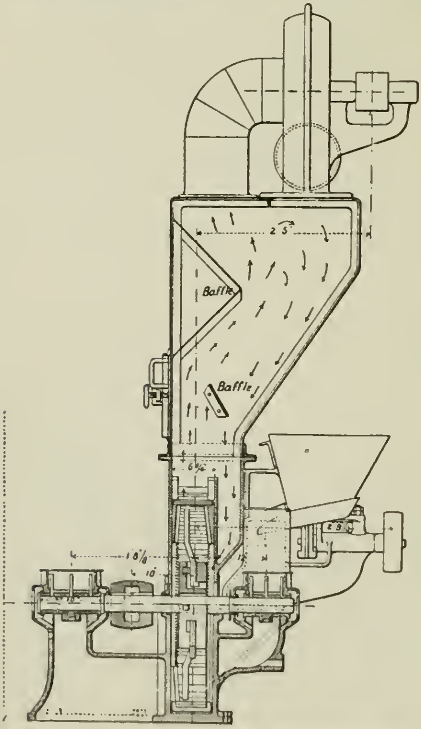
A successful apparatus for use of powdered fuel must conform to the following requirements: A—It must be self contained; B—It must grind and feed the coal with less than 5 per cent of the horse power developed in the boilers; C—It must be possible to attach it to the boiler front; D—It must be an apparatus which can be instantly thrown in and out of gear, with some positive drive which is driving other similar devices in a battery of boilers; E—It must grind and feed separately at least 1,000 pounds of coal per hour; F—It must be of small first cost.

In the Cyclone system, the grinding is done in a pulverizer which receives the coal in pieces of quite large size and by means of a wheel armed with heavy spokes called beaters this machines reduces the coal to a powder. By means of a current of air which enters the machine at or near the place where the coal enters, which current of air is also present with the coal all the time it is in process of being ground, the particles of coal of the required mesh are lifted out of the machine and delivered as soon as they have reached the required size, and all larger particles are returned automatically to the grinding chamber for further reduction. The powder is delivered by the pulverizer into a settling chamber.

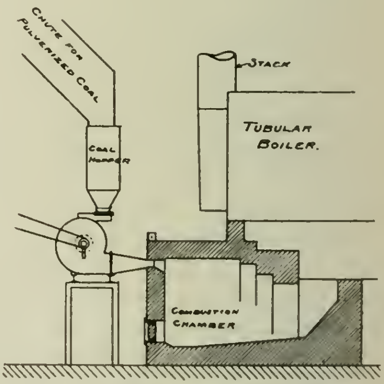
It is not necessary to dry the coal previous to pulverizing it, experience having shown that as much as 10 per cent of moisture will be extracted from the coal by the air current, if that much be in the coal when delivered to the pulverizer, and as 5 per cent or even 6 per cent of moisture in the powder does not interfere with the conveying or the burning of it, the coal before grinding in these pulverizers can contain as much as 15 per cent of moisture. This does away with the danger and expense of the drying of the coal, and is a great advance upon all previous methods. This is possible because no sieving cloth or mesh of any kind is used in the pulverizing machinery, the regulation of the size of the powder being accomplished by alteration of the speed of a fan exhauster which is placed on top of the pulverizer to create the current of air referred to. You will understand of course that for any pulverizing machine in which a sieve is used, the coal must be dried before grinding because if the material be damp it will clog the sieve.

The coal having been reduced to a powder of the required mesh, it is conveyed to the front of the boiler by a worm conveyor and is there delivered into the hopper of a machine which is called a "feeder;" this machine consisting of a hopper, a short worm conveyor, and a fan blower, and the entire machine is operated from the spindle of the fan, the supply of coal being adjusted to meet the requirements of the boiler and the supply of air being also subject to very close adjustment. The worm gear on the spindle of the fan, which operates the conveyor which delivers the coal from the hopper into the fan, is held in place by a lever with a spring catch, and if at any time it is necessary for the supply of coal to be cut off, one movement of that lever stops the delivery of the coal into the combustion chamber; and a movement of the same lever in the opposite direction starts the supply of coal again. Once this feeder has been adjusted correctly as to the supply of coal and of air it is only a matter of the speed at which the machine is operated to either increase or diminish the supply of heat delivered to the boiler. The system can be applied to almost any boiler.

Realizing that to make any system effective it must work successfully under every condition, the people who have perfected the Cyclone system experimented with it in every possible way for over two years after its practical completion before attempting to place it on the market; and the result is that they are now in a position to apply it to almost any kind of a boiler including the Lancashire, Cornish, Belleville, Babcock & Wilcox, Stirling, and Climax, besides other types of boilers.



Sectional Elevators of Cyclone Pulverizer.



Cyclone System Applied to Tubular Boiler.

One important factor which they have had to deal with is one that I touched upon almost the first thing in my talk to you this evening because it is one that has caused considerable trouble in all experiments with the use of powdered coal for fuel under steam boilers, and that is the durability of the brick lining of the combustion chamber, and in carrying out their experiments in this direction my friends in England have used bricks made in many countries including some from the United States and Belgium and France as well as those made in England and Scotland; and they have melted bricks in quite a short time, but they have found the bricks used in the combustion chamber enables it to stand for at least 60 days without repairs, even under the trying conditions of firing only during the day time and closing down at 5:30 p. m., so that the bricks in this way have been exposed to constant expansion and contraction.

Some doubt has been expressed as to whether it is possible to build a combustion chamber which will stand the heat developed in burning such a large quantity as 1,000 pounds of coal per hour in the powdered form, but the experience gained tends to show that it is rather a question of the size of the furnace, for this must correspond with the quantity of coal to be burned.

It has been asked whether there is danger from storing a quantity of powdered coal, and whether if it contains much moisture it will pack into a solid mass. Neither of these contingencies have ever been experienced by parties using the Cyclone system, although the pulverizing machinery referred to is in use by some of the largest Portland cement makers of the world and many thousands of tons of coal have therefore been ground in this machinery; and I might say further that when mixed with the necessary proportion of air powdered coal will not explode until it is heated to the point of giving off its gasses. At the maker's own plant the pulverizer delivers the coal into a canvas room or settling chamber, which is of course full of suspended coal dust. It has been entered with a lighted candle, without the slightest indication of explosion, and this is attributed to the fact that the current of air keeps the coal cool during the entire process of grinding so that the coal in suspension in the canvas room is not giving off any gases and therefore is not explosive.

No smoke comes from the smoke stack. At the plant in London to which I have referred, the chimney is only 33 feet high and a gas engine is therefore used to force the draft and yet the average temperature of the flue gases leaving the boiler is only 413.5 degrees Fah. and leaving the economizer is only 313.5 degrees Fah. They have obtained as much as 17.47 per cent of CO_2, but that is is higher than they consider it wise to work at, and as a rule they get 15 per cent CO_2 or about 1.2 times the theoretical quantity of air, which is very close for actual practice. They get no CO at all, and this is due to the thorough admixture of the air with the coal and also to the fineness and uniformity of the coal powder. The excess of air being so greatly reduced, thermal efficiency of the boiler is greatly increased, the heat not being required to warm an excess of air to chimney gas temperature.

An abstract of a report of Burstall & Monkhouse, on a test made for the Central Cyclone Co., in May, 1903, follows:

> The boiler is an ordinary Lancashire boiler, 8 feet in diameter and 30 feet long, with two flues. It is set in the ordinary way, and has an economzier placed between it and the chimney. The chimney is a very low one, and the necessary draught is obtained by a suction fan placed at the base of the chimney and driven by a gas engine. The draught on the test was equivalent to about 0.3 of water, which would correspond to that from a chimney about 80 to 90 feet high under ordinary circumstances.
>
> The boiler was fitted with your system for firing with powdered coal. The whole apparatus worked with little or no attention, and occupied little space. A very perfect combustion of the coal was obtained, as was shown by the large percentage of carbonic acid obtained from samples of the products of combustion collected from the end of thefurnace, the analysis of these samples giving the following percentage results by volume: Carbonic Acid, 15.1; Carbonic Oxide, 0.0; Oxygen, 3.5; Nitrogen, 81.4.
>
> The perfect combustion also had the effect, as might be expected, of giving a total absence of smoke. The coal used contained a fair quantity of incombustible matter, as shown by the analysis; this formed a liquid slag which collected at the bottom of the furnace, and was raked out at intervals of about four hours. The operation of raking out the slag took only about four minutes for the two furnaces, and compared very favourably with that of cleaning fires, which would have to be done at least once or probably twice during the test with the class of coal used.
>
> The coal used was Durham Wallsend screenings, a class of coal which would not be suitable for steam raising in an ordinary boiler furnace. It was quite small in size, and was pulverized as required in a machine close to the stokehold.
>
> The results of the trial show that the actual water evaporated per pound of coal amounted to 8.4 pounds at an average pressure of 100 pounds per square inch, and from feed water at 57 degrees Fahrenheit. Reducing to standard conditions, the evaporation per pound of coal from and at 212 degrees Fahrenheit is 8.6 pounds of water for the boiler alone, and 10.1 pounds for boiler and economiser. The coal used had a calorific value of 12,728 B. T. U. per pound, so that the efficiency of the boiler alone was 65.4 per cent, and the boiler and economizer 76.5 per cent, a very good performance for this type of boiler.

Mr. Neville—I have been very much interested in this subject of pulverized coal for the past three years. My interest has led me to experiment with it under steam boilers and my experiments have led me to try and get as much efficiency out of the coal as possible and still find an apparatus that will produce good results under a boiler, without damage to the furnace or boiler, and procure an apparatus so that if accident occurs in any part of your pulverizing plant or feeding apparatus, same can be removed from the boiler and firing can be continued by hand, by this means preventing the necessity of a shut down of the plant, as is the case in most apparatuses for burning pulverized coal.

The vital question involved is the amount of water that can be evaporated with a pound of coal, mechanically stoked or pulverized and burned in suspension, and as compared with hand firing; my experience has proven that in some cases an increase up to 50 per cent has been gotten.

I appreciate all that Mr. Sweeney has said and am familiar with the plant to which he refers, and in which I was especially interested during its trial. I also know the malleable plant Mr. Sweeney refers to and have been more or less familiar with practically all the pulverized coal installations that have appeared within the last three years, and from my experience I cannot agree with some of the gentlemen in that I do not think it is practicable to pulverize coal and deliver it directly from the mill into the furnace. There should be a reserve and surplus that can be controlled and handled as desired.

To my mind, one of the first and prime requirements in handling coal for a pulverized process is to remove the moisture as a first operation, and my observation is that the more moisture there is in the coal, the harder it is to control and get good results under a boiler and also to get satisfactory results from the pulverizing machinery. I have known cases where the capacity of pulverizing machinery has been doubled by a reduction of moisture in the coal from 1½ per cent to ½ per cent. This may not hold good in all grades of coal but will in some cases.

Some of the gentlemen have had considerable to say about the danger of explosion in this connection. I have been able to learn of but one case of explosion and that is admitted to have been caused by mechanical defects in the pulverizing machinery. I have known a number of cases of spontaneous combustion but in these cases the combustion was very slow and with any care at all no serious damage can result.

People who use large quantities of pulverized coal, especially in connection with Portland cement plants where they are careful to handle the coal in iron tanks and bins throughout, have no apprehension of danger from fire.

With the boiler tests that have come under my observation recently, taking into consideration the cost of maintenance and the cost of pulverizing machinery, there has been shown a net saving of 5 cents per thousand pounds of water evaporated.

Mr. E. C. DeWolfe—The paper mentions the claims of advocates of apparatus wherein the pulverizing and burning are separated by considerable distances, that liability to explosion is lessened by this arrangement. It is probably true that one of the most disastrous explosions in connection with powdered coal plants, both in property loss and in personal injuries and fatalities, was that at the Edison cement works, New Village, N. J., some months ago. In that plant the coal was pulverized at a considerable distance, perhaps 300 or 400 feet, from the rotary kilns in which it was used. The powdered fuel was then carried by conveyors to a large blower house, from which other conveyors led to a storage hopper, located in a building adjacent to the kiln house, but detached from it. From this fine coal store house the fuel supply for the rotaries was drawn as required. After the explosion, which occurred at the blower house, the company undertook to overhaul the system in such a manner as to avoid the possibility of a recurrence. The aim in each step of the alterations was with the powdered coal at any point between the beginning of the pulverization and the feeding devices at the kilns. Previously the coal grinding was done by means of the same type of roll machines as are used in the rock and clinker grinding for the cement processes themselves. Separation of coarse from fine was accomplished by currents of air. The company has now installed a pair of simple ball and tube mills for the coal grinding, and has cut out entirely from the circuit the blower house. The coal is conveveyed directly from the grinding house to the small storage building immediately adjacent to the kilns. The storage capacity here is comparatively small, and it is believed that difficulties from air mixture with the coal are done away. What the results will be, only time will tell. The point is that, as I understand it, regardless of the method of feeding and burning coal, the fuel in the powdered form must be very carefully handled and stored.

Mr. E. H. Stroud—I can account, to some extent, for that explosion. Formerly they ground their coal through several pairs of crushing rolls, to reduce it to the required fineness. It is a well known fact that any system of roller device for grinding heats the coal. Furthermore, they carried this coal away by air suction through large pipes for quite a distance, and with considerable velocity. There was considerable rush of air through the pipe, and the pipes became quite warm; the coal, therefore, that was carried through these pipes was *warm*, to say the least. Mr. Mallory, the Vice President, has written me about the "Cyclone" pulverizers for coal, so that they are not yet entirely satisfied with the plant.

Mr. Sweeney—I heard that the Edison explosion was traced back to the fact that at one time the coal was carried on a kind of open conveyor; that the collection of a large amount of coal dust was made through a comparatively small tunnel house, and that this got afire in some way. I think the statement in the paper referred to is not quite of that caliber. What was intended to be conveyed was the idea that a machine, taking the air into it, mixing it with the pulverized coal, and discharging it into the furnace, was more liable to have an internal explosion, due to back firing.

I would like to ask Mr. Stroud if there is a plant such as he describes that can be seen in or near Chicago?

Mr. Stroud—There is no plant of our " Cyclone " in operation in this country, as yet. It is but a short time since efforts have been begun to introduce it here.

Mr. Sweeney—I have not yet been able to cipher out where the energy comes from; at so low a cost it is not accounted for. If you take 5, 10 or more per cent of moisture out of the coal, you must furnish that energy somewhere.

Mr. Stroud—We use the very cheapest and most plentiful thing we can find on God's earth to accomplish that—viz., air. You will notice that we admit air into the pulverizer with the coal, and that air is present with it all the time in the process of grinding, and as the particles grow smaller and smaller, they are surrounded all the time with air; and if you would know the power of air to absorb moisiure I would remind you how quickly a wet street is dried if the wind starts to blow.

Mr. Massa.—I would like to mention a test which I did not make but saw made, of a pulverizer working on almost this same principle, in which the pulverizer ran along all right when the coal was dry, but when the coal was wet the power required was so high that it nearly burned out the motor.

Mr. Mayer.—I would like to ask Mr. Stroud what system he has to prevent the arching of the coal in the hopper.

Mr. Stroud—We have in the hopper a conical shaped piece of metal or wood covered with graphite, which is at the end of a rod that runs up through the centre of the hopper, and is operated by a little lever that comes over the side.

Mr. Massa.—I would also like to ask Mr. Stroud if he has any record of expenses in maintaining a machine for grinding any certain number of tons of coal?

Mr. Stroud—The "Cyclone" pulverizers are now in operation at some of their largest works and have been adopted by the "Associated Portland Cement Makers of England" for the grinding of their coal, wherever they run rotary kilns, therefore we have abundant opportunity to not only know what they will do on wet and dry coals, but also what the wear and tear account is. The experience we have had is that the expense for wear and tear does not exceed 1 cent per ton, and very seldom equals that.

Mr. C. D. Stephens—Reference has been made to the Illinois Central R. R. Co.; I have some knowledge of the experiments that have been going on down there, and it might shed a little light on the subject to state what has been done and what they are now doing. About three years ago, I was connected with the concern that furnished the apparatus for delivering pulverized coal to the pair of horizontal tubular boilers, under which the original experiments were made for the Illinois Central R. R.

The preparatory apparatus, consisting of a Clark crusher, together with necessary elevators and conveyors, was contained in a long narrow room about 9 feet wide. The apparatus was driven by a 50 H. P. induction motor. The operation of the pulverizer and the elevating and conveying machinery was not very satisfactory. They did, however, make a good many tests, which I presume are a matter of record.

The apparatus was taken out and about a year ago I was engaged to design a plant for the preparation of the pulverized coal for use under four new boilers which were put in at the 27th St. Station. The design entailed such a large expense, and as it was late in the Fall, the plan was abandoned and the water jacket legs and combustion chambers, which had been placed under the boilers for the pulverized coal, were removed and the boilers have been hand fired for the past Winter, on account of the necessity of having their steam.

We are at present erecting the horizontal dryer made by the C. O. Bartlett Co. of Cleveland. It is proposed to take the coal from cars and, by elevating it, send it through the dryer. From the dryer it will be discharged to another elevator, which will put the dry coal into a hopper over the Clark pulverizer. From the pulverizer, it will be delivered by an elevator to a feeding hopper, from which the coal will be carried to the boilers in sacks. This outfit will be used for experiments which will be carried on probably during the present Spring and Summer.

CLOSURE.

Mr. Sweeney—It was the Cyclone pulverizer referred to in the early part of the paper, as having been used in some of the experiments of Mr. Winans, and I believe to-day much better means of pulverizing coal are found in machinery of different construction, such as the Griffin mill, which is extensively used in work of this kind. I can see no benefit in the air draft talked of, because any of these machines makes a sufficient amount of air to produce the same effect. In cases of coals pulverized under conditions where it might have been claimed that the heating of the coal in pulverizing detracted from its heating unit value, chemical analysis has demonstrated that the coals were in no way injured. What may have been done in England with one kind of coal is not necessarily proof as to what may be done with other kinds of coal, and we can tell more about the Cyclone when it has handled the coals which were encountered in the cases referred to in this paper.

ELECTRICAL SECTION: W. S. E.

THE OPPORTUNITIES IN THE ELECTRICAL BUSINESS.*

MR. GEORGE A. DAMON, M. W. S. E.

The electrical business is a complicated one, and is constantly undergoing changes. By the time a method or system becomes standard enough to be looked upon as a precedent, a tendency develops in some entirely new direction. The men who succeed in electrical work must therefore be quick to grasp the lessons of the past, must be ready to appreciate the limitations of the present and above all should be alert to seize the opportunities for improvement.

The leaders in the various branches of the industry during the first developments when electrical work was an art and not a science, were graduates from the well known university of "Hard Knocks." The men of the second generation of workers who are now doing things are largely the product of a semi-scientific training in schools of technology, supplemented by experience of a practical nature picked up in a more or less haphazard way. A few years more will see the development of a third and better prepared generation of electrical experts, and it is safe to say that they will be the result of a combination of a practical training thoroughly mixed with a theoretical education. As it must be expected that the next generation will be superior to the present one, will it not be well to stop for an instant in the strenuous rush for results and make a few suggestions which may be of assistance to our successors in planning their life work.

"Work harder," "dig deeper," "put in a better cement foundation," are the key notes of the suggestions which our older brothers give to us as the result of their experience, and the ambitious young man will be quick to recognize the value of their advice. But what is wanted most is some definite information as to how to spend the time devoted to preparation in the most efficient manner, and how to get the benefit of a combined training in theory and practice in the most effective way.

THREE INQUIRIES.

That those who have traveled well on their way toward their goal will have many opportunities to point the way to the ones behind, is well indicated by recounting several recent conversations. The first was with a boy of eighteen.

"I am a Senior in the High School," he said, "and I want to become an electrical engineer; what shall I do?"

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*This paper was presented at the first meeting of the Electrical Section of the Western Society of Engineers, held March 18, 1904.

He was strong, bright, ambitious and willing to work.

"Some men tell me to take a college course first and enter practical work afterward; some tell me to get a few years' experience first and then take a college course, while still others tell me to study several years, work a year or two and then finish my Senior year. In planning my course should I include the language studies or cut them out in favor of shop, laboratory or commercial courses? Should I try to get through in three years, or should I extend my college education over a period of five years? Others tell me to leave out the university work entirely, go to work in the shop or upon construction work, getting what theoretical training I require by attendance at night school or by taking a correspondence course. What shall I do?"

And there are some of us who will appreciate the young man's bewilderment.

The second conversation was with a professor at the head of the electrical department of one of our leading universities.

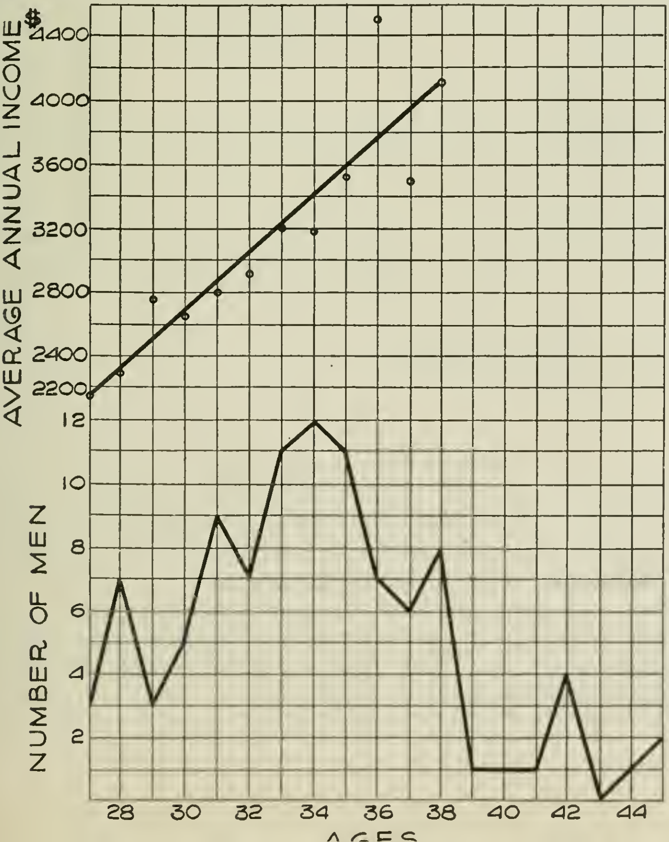
"I feel highly complimented," he said. "I have received a letter from one of the largest electrical manufacturing companies in this country, offering positions to my entire senior class. This is remarkable, for in Europe it is the custom for the technical graduates to pay for the privilege of entering the shops of the large companies. But," he continued, "I should like to find out whether or not I should advise my boys to accept this offer. What has become of the young college men who entered the shop courses in years gone by? Are they advancing as satisfactorily as the graduates who found positions in other parts of the field? Have the large companies taken care of the graduates of their testing departments with sufficient liberality to justify a young man in making the sacrifices which a shop course entails? Would it not be better all around if I offered the large company the services of my Junior class for one year? What would you advise?"

The professor is to be commended in his search for information, and in his evident interest in seeing his "boys" get a fair start in the strenuous race in which they have entered.

The third conversation was with a young electrical engineer who had graduated from high school, had then taken a college course with some practical work during vacations, and had then entered a large factory as a "special apprentice."

"I have had a fine experience," he said, "and have nothing to regret. Upon leaving college I went into the testing department of a large electrical manufacturing company, was promoted rapidly, and finally advanced into the engineering department. My compensation at first was small, but it has gradually been increased until at the end of five years' service I am receiving about $1,500 per year. I am looking out for the future, however, and am not entirely satisfied with the prospect. If I stay with my present employers, the manufacturing company, my work must be narrowed to one department of the work, and I will always be a salaried man without an opportunity to acquire an interest in the business. Would it not have been better for me to have started with a smaller company, and is it too late yet for me to begin over again? What would you suggest?"

Knowing that the leading electrical men of Chicago would afford a valuable field for studying results and would welcome an opportunity to help furnish a solution for the problems of the boy, the professor and the rising young electrical engineer, a letter of inquiry was sent to one hundred of the leading men in Chicago engaged in the various branches of the electrical industry. An opportunity was given at the same time for the expression of opinion on various questions pertinent to the general subject. The response to the circular letter was hearty and spontaneous, and we are under obligations to one hundred of our friends who have so kindly consented to become living examples, and willing to be analyzed for the good of the cause. The following is



AN ANALYSIS OF RESULTS.

Young men control the business. The inquiry was, therefore, confined to men between the ages of 27 and 45, upon the theory that the older men are the product of a set of conditions which have passed away, while the youngest men are, as a rule, still engaged in a period of preparation. The number of men of each age is shown graphically. The average age is thirty-three and one-half years.

The average income at each age is also plotted on a gunshot diagram and a line of average incomes determined up to the age of thirty-eight, after which there was not sufficient data to locate the curve. This income curve starts with a value of $2,170 at twenty-seven and extends to $4,000 at the age of thirty-eight. The average income of the entire one hundred men is $3,440 per year, which will give us a standard by which we can measure the different branches from a mercenary standpoint.

The hundred men may be divided into groups as follows:

	No. of men	Average Age	Average Income
Salesmen	7	33	$2,400
Sales Managers	11	36	3,400
Business Men	10	36	4,800
Sales Engineers	8	35	2,350
Electrical Engineers	16	33	2,800
Constructing Engineers	6	33	2,850
Electrical Experts	8	33	3,200
Operating Engineers	3	32	2.250
Operating Managers and Superintendents	10	34	3,550
Professors and Editors	8	34	2,500
Patent Attorneys	4	32	4,000
Consulting Engineers	9	40	6,400

Total number of men, 100. General Averages: age, 33½ years; income, $3,440.

Classified in reference to incomes, the record is as follows:

	Men
Income over $10,000 per year	5
Income between $5,000 and $10,000	9
Income between $2,400 and $5,000	66
Income below $2,400	20
Total	100

It should be stated that there are in Chicago at least one hundred more men in the business whose incomes will average about the same as the first hundred selected. An effort was made to make the list representative, and the men were selected on account of their positions without reference to their incomes.

It is to be understood that the dollar is not the most desirable standard by which to measure men individually, but looked upon as a class, a study of the averages furnished by the inquiry is interesting and may be made instructive.

Salesmen who have technical ability or possess engineering information, as a rule, get better salaries than those who do not.

Add initiative and executive ability to the salesman's ability and he becomes a sales manager with a still greater reward.

Enterprise and energy put the man in possession of his own business, or often result in a partnership arrangement. A technical man without the commercial instinct is only fairly well paid. Ability to develop new methods or apparatus puts him in the expert class where the rewards are greater and in proportion to his ability.

Routine work, such as operating, is the least remunerative work of all. Operating managers and superintendents however, are very well paid.

The editors were classed with the professors as there were too few to form a class with an average of their own.

Our professors should form a union, as they are certainly entitled to higher compensation, and as we all appreciate their value we would help them win should they decide to strike. We must grant however, that they get rewards in seeing the living results of their work, which is a compensation worthy of considerable sacrifice.

The phenomenal development along all electrical lines, and particularly in the telephone business, makes the profession of patent attorney a paying one for those who are qualified for that kind of work.

The field of consulting electrical engineering looks attractive, but it will be noted that the average age is greater in this branch than in the others, which means that the successful consulting engineer brings to his work years of experience, and that it is therefore not a branch to be adopted at once by the young man.

Forty per cent of the men in the list are employed by what might be termed the "large" companies, such as the Western Electric, Chicago Edison, Chicago Telephone Company, etc.

Thirty-five per cent of the men either control the business in which they are engaged or own a partnership interest.

Twenty-five per cent of the men are not college graduates.

Twenty per cent of this hundred successful men never had any college education whatever.

The average age of the twenty men who are succeeding without a college education is 36 years, and their success measured by a monetary standard shows an income of $3,670 per year.

The average age of 16 graduates of Cornell is also 36 years, and their success measured by the same questionable standard is $4,940, which shows a balance of $1,270 per year in favor of a college education.

It will be noted however, that the twenty men without the education are getting along financially slightly better than the general average of $3,440 per year. This is explained by the fact that in their number are included several men who are prospering as a result of their business enterprise.

There are few non-technical men engaged in the strictly technical end of the business who reach the average income.

There seems to be more openings for the man without a college training in the telephone field than in any other.

The inquiry into the domestic arrangements of our hundred examples shows that 75 per cent of them are married. The families are composed of 45 boys and 30 girls.

Out of the hundred men selected only 56 per cent belong to the American Institute of Electrical Engineers.

The answers to the questions upon which an expression of opinion was asked resulted as follows:

Eighty per cent are inclined to think that a college education is essential to the highest success.

Seventy per cent are in favor of the technical graduate taking a shop course in a large manufacturing company, but many wished to limit this course to one year.

Fifty-five per cent are of the opinion that in choosing a life work better chances for advancement will be found with the smaller companies.

Seventy per cent are in favor of requiring a year's practical work of the student before graduation.

Fifty-five per cent agree that the larger companies would be consulting the interest of the art at large by offering an apprentice course open to students during an intermission of one or two years before completing the senior year.

The exact wording of the questions, to which some objection was made, and a number of instructive and qualified answers to each are given at length in the addenda. These opinions from men actually "doing things" are well worth careful study.

OPPORTUNITIES.

Each of the hundred men included in the inquiry were asked to name the three fields which he considered most promising within the immediate future and the votes received are as follows:

Electric Railway Work	63
Telephony	36
Transmission	30
Electro-Chemistry	29
Power Applications	21
Lighting Developments	12
Manufacturing	11
Central Station Work	9
Patent Law	6
Consulting Engineering	6
Contracting	5

Management of Properties	5
Storage Batteries	4
Reconstruction of Plants	3
Mining	3
Metallurgy	3
Turbines	2
Wireless Telegraphy, Designing, High Speed Telegraphy, Underground Conduit Construction, Isolated Plants, Train Lighting and Municipal Lighting, each	1

As a result of personal observation, tempered somewhat by the opinions of the electrical men, with whom the questions have been discussed, the writer wishes to present the following conclusions:

A COLLEGE EDUCATION.

A young man wishing to succeed in any branch of electrical industries makes a serious mistake if he fails to use every effort to obtain a technical education. A college course is becoming easier to obtain and it is already recognized as a general requirement for advancement. A young man of high aspirations, who is so situated that he cannot secure a university course, might better, nine times out of ten, take up some other branch of work which is less intricate than the electrical art. Thomas Edison, the Dean of the profession, is not a college man, but a gold medal bearing his name is to be given hereafter each year to the college graduate presenting the best thesis, and this incident is the best evidence of the present tendency toward technical education. Nearly every man who is now making his way in the electrical business without a college training, if asked what he would do if he had his life to live over will say: "I would secure a technical course in the best college I could find."

CORRESPONDENCE SCHOOLS.

A technical course in a correspondence school which can give the proper training for an electrical engineer is yet to be produced. The correspondence schools are doing a good work and are to be recommended to those who cannot possibly avail themselves of a college course or get instruction in evening school, courses such as offered by Armour or Lewis Institutes, but a young man who will deliberately choose correspondence instruction if anything else is available is making a serious mistake. Of the hundred men in the list only two had completed a correspondence course. These two men were engaged in telephone work, and both voted in favor of a college course.

PRACTICAL EXPERIENCE.

Practical experience is as essential as theoretical training. Too little attention has been paid by students in getting into thorough contact with the way things are actually done. This is the result of the general practice of allowing the young man to shift for himself. "I can't get a job without experience," he says, "and I can't get experience without a job;" and then, more or less discouraged at the outlook, he takes the first opening which presents itself, and it may or may not be the kind of work for which he is fitted. What is needed is a general clearing-house of information, a closer union between the ambitious student and the successful men who have been pioneers in the work. The electrical business has now progressed far enough that the actual experience essential for the highest success along any one of its various lines can be generally indicated by experts familiar with the ground to be covered. It is time therefore, to abandon a thoughtless and perhaps selfish attitude toward the beginner and make some organized effort to map out the territory which he must travel with guide posts and signs marked: "This Way to the Front."

An association of thoroughly successful men should exercise some supervision over the preparation of the coming generation. If it is true that the art is suffering today from a lack of trained men ready to take up and solve the problems which are all about us, what must we expect of the morrow with its widening opportunities? The student branches of the American Institute of Electrical Engineers and the recently formed Edison Medal Association are moves in the right direction, but only a beginning toward realizing the possibilities. Considerable attention is being given to develop the best technical course, but a college training is less than half of an education. What constitutes the other half is a big problem waiting for a comprehensive answer.

SHOP COURSES.

The policy of the large companies in offering apprentice courses and opportunities for experience in their testing departments is to be commended. This practice, as carried on in some cases, however is to be criticised. A representative of a large manufacturing company visits a technical school, offering to give positions to all the members of the Senior class; the professor is highly complimented at this remarkable courtesy, and advises his students to accept. The "shop" course usually covers a period of two years. The hours are long and the pay is small. The "experience" gained by the student may or may not justify the sacrifice. "It depends largely on the man." In the meantime the large company has a good opportunity to select the material which it requires for its own use, and perhaps twenty-five per cent of the shop graduates have reason to feel enthusiastic over the system; the others pass through days and nights of discouragement, and many leave the shop with a sense of failure, which is sure to have an influence on their future.

All men are not built alike. Then why grind them through the same mill? Should not some selections of materials be made before the mills are started, a sorting over made earlier in the process? Perhaps the mills themselves could be made a little more efficient. It does seem possible that a commission made up of the broadest men in the profession, some from the large companies and some from outside practice, could do much toward improving the facilities and present systems for "getting experience." On behalf of the students now in the colleges who have still to face the practical problems, an appeal for help, information and suggestions is made.

THE STUDENT'S PART.

The trouble with a great many young men is that they don't "find" themselves early enough in life. They fail to realize the possibilities and are not prepared to grasp their opportunities. Ambition, Aptitude, Preparation and Hard Work are the stepping stones to successful attainment. Let the ambition to excel be deeply seated and directed along the lines of natural endowment; let the purpose be firm, and as day follows night the preparation will be thorough and the man will be known by his works. "If I had it to do over again I would pick out some definite line of work suited to my talents and work like fury" is the advice of many successful and even unsuccessful men.

The purpose of this paper is to encourage a general discussion, which may be of some help in arousing the latent ambitions of the young men who have not selected their life work, by showing them the boundless opportunities of an undeveloped science; to encourage the efforts of the students in our colleges by presenting the results which have been attained by their predecessors; to crystalize the sentiment in favor of a scientific combination of theory and practice, and finally, to give an opportunity to the men on the fighting line to point the way to their successors who must come to the front prepared in every way, if they intend to take some part in the phenomenal developments which are to be expected.

In order to direct the discussion along definite channels the following is offered as a suggestion to a young man seriously considering engaging in the electrical business:

A SPECIFICATION FOR SUCCESS.

In general—The purport and intent of this specification is to cover the labor and material required to produce in complete working order a man prepared to attain his own ideal of success in that branch of electrical work which he may elect.

It is to be understood that the omission of the mention of small details in this description does not obviate the necessity of their being furnished. What is wanted is a thoroughly trained, well seasoned, broad minded man, complete with an individual character, a strong intellect, and a sincere purpose.

Plans—He will form his ambition early in life.

He will take a natural interest in the history of men of eminence in his chosen work and their achievements will inspire him with a desire to accomplish great things.

He will develop his imagination and constantly broaden his conception of his own possibilities.

He will seek to learn what the world wants and then will endeavor to train his natural abilities so as to supply that want.

Foundations—He will as a boy develop a knack of "doing things" either as a mechanic, as a draftsman, or in some boyish business enterprise, and a combination of any two or all three proclivities is desirable.

He must early learn the advantage of doing some one thing well, but he should not allow praise for his proficiency to encourage him to neglect study along the lines he does not naturally fancy.

He will prepare for college and during this period of preparation he will get enough experience in practical work to demonstrate that he has made a wise choice for his life work.

He will not let the attractions of practical work interfere with his intentions to secure the best theoretical and technical training the country affords.

Dimensions—He will endeavor early to "earn money" by doing useful work, and will seek employment outside of his study hours. Everything he attempts he will complete to the best of his knowledge and ability.

He will put himself on a self-supporting basis as soon as possible, and will earn his own way through college. If he receives financial assistance, he will treat it as borrowed money, to be returned, and he will keep the debt within reasonable limits.

He will not allow any false sentiment "to finish with his class" prevent him from stopping out one or even two years during his college course to add to his store of practical experience along electrical or allied lines.

He will determine for himself whether he intends to realize on his possibilities quickly or whether he will lay a broader foundation for a slower but higher development.

General Design—Each bidder will state the percentage which he is prepared to guarantee in connection with the following qualities:

Health
Ambition
Honesty
Truthfulness
Temperance
Decision
Purpose
Up-to-dateness
Originality
Energy
Industry
Stick-to-itiveness
Grit
Thoroughness
Neatness

Self-control
Patience
Cheerfulness
Self-respect
Self-reliance
Courage
Observation
Common Sense
Initiative
Enterprise
Enthusiasm
Concentration
Executive Ability
Scholarship.
System
Dispatch
Punctuality
Judgment
Tact
Good Manners
Capacity for Hard Work

Consideration will be given to guarantees of high efficiency of each item. It is suggested that all of these qualities be carefully measured.

Capacity—Even if the young man possesses only ordinary talents, his capacity for hard, conscientious, intelligent, well-directed work will attract attention and win advancement.

When the occasion demands he will be able to stand a long run on overload or respond to excessive demands for short periods without permanent injury.

He will be able to direct others and will not depend entirely upon his unaided efforts for results.

Operation—He will work quietly, and will be turning in the right direction every minute in a simple, direct, and accurate way.

He will join that great army of workers who are actually doing things rather than that smaller class of men who occupy most of their time in telling what they are going to do.

Parallel operation—As a student he will enroll as a member of the Student Branch of the American Institute of Electrical Engineers and take a lively interest in the Institute papers and discussions. In practice he will advance to Associate membership and will look forward to the day when he has added sufficient to the art to be considered worthy of Active membership.

If he locates in Chicago or in the West he will become a working member of the Electrical Section of the Western Society of Engineers.

He will make friends among his superiors, who will respect his ambitions and will be glad to assist him in realizing his ideals.

He will study men and know how to deal with them.

Work to be done by others—Parents should study their children and encourage them to develop their natural tendencies.

Teachers should get hold of their students personally and as far as possible treat each case individually.

More occasions should be made for successful men to meet students and give them the benefit of their advice and experience.

The students should not be isolated in a little world of their own, but should be brought in contact with an atmosphere of actual affairs.

Above all, some method must be devised to guide the young man to and through the course of practical experience best adapted to his qualifications and purpose in life.

Shop tests—If he enters the shop or testing department of a manufacturing company, he will make a bargain which will result in his getting an all around experience in exchange for his services, and, while in the shop, will keep on the move in every sense of the word.

He will seek to make himself thoroughly practical in all his ideas and methods of work.

Finish—He will include in his preparations considerable literary work and will seek after a general culture. He will study at least one foreign language.

He will regard his college work as only the beginning of his education and will be a student always.

He will seek practice in the art of expressing himself, and will occasionally write a paper on some technical subject.

He will become interested in some social, educational or reform movement, and will avoid becoming a recluse interested only in his own work.

Inspection—During his Senior year he will submit a thesis in competition for the Edison Medal and even if he fails to get the prize his effort will demonstrate his sincerity and will show the thoroughness and breadth of his preparations.

Fittings—He will find it necessary to possess accurate knowledge of nearly every branch of science, including physics, chemistry, mathematics, mechanics, pneumatics, hydraulics, mining, metallurgy, and civil engineering.

He must know something about accounts and a great deal about business and commercial law.

He will find that the electrical business is so broad in its scope that a natural aptitude in any direction can be made of use.

Completion—He will make every sacrifice to get a thorough preparation and a broad experience up to the age of 28 or 30 years.

He will accomplish much between the age of 30 and 45, at the end of which time he will be well settled in his business or profession.

Let us leave him at this time to inherit his own. May he live long and prosper.

ADDENDA.

The following are some of the answers received in reply to a set of questions sent to one hundred electrical men in Chicago:

QUESTION NO. 1.

Is a college education essential to the highest success?

"It is essential to some but not to others; it is a good thing for any one."

"Yes, unless the man is a very unusually industrious and talented person."

"Unless a man is born with remarkable aptitude for engineering work, he cannot longer expect to surpass those who have been technically trained, and if he has such talent the technical education will benefit him."

"It is more and more going to be that way; there are now ten college graduates in leading positions where there was one only ten or fifteen years ago."

"Not strictly essential, but a potent factor in advancement. I believe a college education gives a person greater adaptability to perform duties of a greatly varying nature, and to acquire proficiency and efficiency more rapidly."

"Yes in at least 75 per cent of the cases. There are, however, qualifications to which some men are born heir which enable them to achieve success in the electrical business sometimes, even as did Lincoln in the profession of law."

"I should say that a college education was very essential to the best success to be attained, but I would qualify the college education with a good, hard, practical training in the shops and in the field. A man who has been 'through the mill' and has not had a college education, can do more work in a month than a college man can do in a year, because he has been, or should take in technical studies when he is off work, whereas the latter cannot take practical work when he is off studies."

"Necessary for an Engineer. Not necessary for commercial success. Necessary for the 'highest success,' which means a well balanced development."

"Not essential, but advisable unless the recipient becomes thereby too 'chesty' to begin down where the concrete starts."

"A college education is certainly advisable for the highest success. It is possible for a man to get an education at home or in business and be as successful as the man spending a term of years in college, but it is not as convenient and he is not as a rule as well educated in every technicality. If he has a strong and determined will that he will climb to success, he, of course, puts in long hard hours of work, if he undertakes to succeed without a college education; whereas, his path is easier if he has time to take this technical training. Experience of course, is an absolute necessity if a man is going to master any profession."

"Not essential but undoubtedly advantageous in business and certainly a great addition to one's enjoyment of life."

"I should say that a technical education was the best means by which a young man could advance himself. The trouble to get along without the necessary education is like a mechanic trying to work without tools. I would say in summing up to start with, a young man must necessarily have some natural ability as a mechanic if he wishes to pursue the practical end of the electrical business. Furthermore, he must be prepared to put in a great many years of hard work if he wishes to succeed. If I may use the word 'stick-to-it-iveness,' I think that will express what I am trying to get at. There are so many young men who have started in to work for the Company which employs me, who made a very good beginning, but who did not last long.

QUESTION NO. 2.

Does a technical graduate consult his best interests by accepting a position as "special apprentice," or work in the "testing department" of a large manufacturing company?

"It depends on whether or not he intends to become a central station manager or strictly an Electrical Engineer. It is desirable in any case, but unnecessary, as time is limited if he intends to be the former."

"Yes, if he does not stay too long in one place."

"Yes, but don't fall into a rut."

"I think he does, provided he does not stay at it too long."

"I think a year of such work is sufficient for a good mind."

"Decidedly, yes. For best results it is desirable that a variety of work be provided, with a fair amount of responsibility involved."

"Only in case he hasn't become expert with testing instruments before graduation (and many have not), or in case he can not get a position that will afford him a broadening experience."

"This depends on what his previous experience has been; a year's experience with a large manufacturing company is of great value."

"Not necessarily, as there are other ways to get practical experience."

"This question can be answered both in the negative and in the affirmative, as the man should first consider his qualifications and natural tact, as well as the particular branch of the industry he will seek to perfect himself in. In most instances however, for a limited time such experience would be highly valuable, but in most cases should not be a permanent thing."

"If he does so to gain experience, yes; but if with the expectation of soon rising to a high position, no."

"Yes, if he does not stay too long with the big company."

"Yes, a graduate cannot be too familiar with the details of standard apparatus. Such information can be easily obtained in the various testing departments."

"Yes, he gets a greater variety of experience there than he will at any other place."

"Under certain circumstances he may. I think he should look the field over very carefully before taking them."

"In my opinion, a technical graduate consults his best interest by accepting a position for practical experience in a testing department of a large manufacturing company where machinery and apparatus are put together, tested, and the results of the designer exposed. In taking all classes of machinery, devices and apparatus produced by a large manufacturing company, he in this way gets the very best results in the line of experience. If he confines his time to some special work, he only becomes expert in that special branch and in a sense is unfit for broad and general work."

"Practical experience at the bottom of the ladder is essential to try out a man and fit him for greater responsibilities."

"This is too broad a question. The choice depends entirely upon what your aim in life is. Experience with a large manufacturing company is without doubt a very great help."

"A safe step to take, but there is other experience which is equally valuable."

"The trouble with the college graduate of today is that he wants to make too much money at the start, and is not satisfied to accept a menial position which might possibly lead to better things in a few years. He jumps at a position which offers a moderate salary without looking ahead, thinking he is pursuing the best course, when, as a matter of fact, he is on the wrong tack entirely."

"The only real practical place to learn any electrical engineering of practical value."

"It depends on the branch one intends to pursue. If he is going to do designing, I would say yes."

"A graduate has a small field of work unless he takes up practical work. Shop practice gives him experience in the shortest time."

Question No. 3.

Does employment with the larger companies offer the same opportunities for advancement as work with comparatively smaller organizations?

"Salary possibilities are greater with the large company. More varied experience with a small company."

"Probably not, but it offers a more varied experience and, as a rule, greater minds as superiors."

"It depends upon the ability and ambitions of the man. In general, a man will fare better financially with the small organization, but if his ambition is to become an official in a large organization, I would advise beginning with it."

"It depends whether he has a relative among the directory to push him; otherwise he is liable to lose his identity and be washed overboard."

"This is rather difficult to answer; it depends upon the person and also upon the company. While they may offer the same opportunities, other things being equal, advancement would probably be more rapid with the smaller company."

"In general, no; yet some men would doubtless find greater opportunities with the large concerns."

"It offers exceptional opportunities to a few of the best, but the others would do better with smaller concerns."

"Not if the men in charge of small ones are as good as the big companies. Nothing better than being 'next' a big man."

"I believe a beginning with a smaller company and ending in a larger one would be the best way."

"As a rule, no. A man with a large company is more generally confined to specific and classified lines, while with a smaller company has the opportunity of a more general research and greater opportunities for advancement with the growth of the concern, considering of course that sufficient conservatism predominates the management."

"For professional advancement, yes; for financial advancement, no."

"Cream comes to the top from a large pan of milk as well as from a small one."

"With large companies advancement is likely to be slower, especially at the beginning, but the possibilities for future are also better to the 'right man'."

"I should say that large companies offer more opportunities for advancement than small companies, because if a technical graduate is on to his job, he will commence at the lowest possible point he can, and go through all the varying duties that may be laid upon him, and so gain experience in all the branches, provided however, that his pocket can stand the drain, as he might not be content to start in at $30 a month and be content to learn something which would enable him to double his salary in a very short time."

"Would advise associating with small companies at first. With business ability, combined with engineering skill, financial success would be greater with small organizations. I believe there is more opportunity for great engineering work in larger companies, and therefore more success from a purely engineering standpoint.

"It has been my experience that no matter what branch of business a young man enters, if he is capable of good hard work, he will finally drift into the department of that business to which he is best suited. Of course there are some companies that are narrow-minded and do not give a young man a chance, but I have not considered companies of this kind. A man will never succeed in any business if he does not like the work connected with it in all its branches. Neither will he succeed if he tries to confine the hours of working each day to any fixed limit."

"Two or three years ago, when I had occasion to make inquiry, statistics showed that of the technically educated students who enter the employ of our company, about half the men continued with the company, the other half finding positions elsewhere. I presume that this is true at this time. We have, as you know, some 300 students in our testing department, and we draw from them not only for openings in our engineering departments, both at our works and district offices, but also for our commercial departments. It is possible that a larger portion of the men would find it to their interest to obtain employment with small local central station or manufacturing companies, but in general the rule is true that water finds its proper level, and I think the above statistics answer the question."

"No. The educational advantages are great with a large company, but opportunities for advancement less for the average man, though the maximum attainment is of course greater."

"No, unless the man is especially clever or has a brilliant personality."

"For men of unusual ability or talents it does; for mediocre men it does not."

"No. In a small organization a man gets a broader view of the business from all sides. In a large concern his view is extremely limited."

"My judgment is that employment with large companies affords more facilities and opportunities for advancement than does the smaller organization, because there is a greater variety of work, giving a man a broader experience and making him more valuable to his employer and to himself."

"General knowledge is more readily obtained with the small company. Detail with the large company. Either affords opportunities for "rustlers.""

"In salaries, yes; but not in the satisfaction a man gets out of his work, nor usually in the breadth of his view."

"Better, if he knows his aptitudes and has determined on his proper line of work. Not so good, if he has not yet 'found' himself."

"Men do not get rich 'on salary.' Employment with a large company means little or no opportunity, even to gain interest in the concern. The 'good' man does better in the small concern; the 'exceptional' man in the larger one."

"Not the same; but opportunities greater in extent and number and importance than smaller organizations."

"No, I think not. Large companies have a few good positions but the chances of obtaining them are few."

"My opinion is that more rapid advancement is realized with the smaller companies, and the ultimate degree lies largely with the individual."

"I do not think it does. In the large organizations there is a tendency to get into a rut, and a temptation to stay in."

"I believe it is about an equal thing, but personally favor the smaller organizations."

"No, a young man in a large corporation is merely a cog in a wheel and has no opportunity to become acquainted with other departments. A young man could wisely spend a little additional money and work for nothing or even pay for the privilege of being able to work in all the various departments in large companies."

Question No. 4.

Would it not be a good rule to require a year's practical experience before completion of the college course?

"Not by skipping a school year; should have the experience but get it during vacations. Get out of school as soon as possible."

"I believe it would be advantageous, although the same benefits might be obtained by vacation work."

"Yes, if the man has the nerve to go back and not allow some one to talk him out of it."

"A year at practical work would be very valuable from the fact that it would serve to show students where their college training could be made to apply."

"Yes and No. Yes, because it would increase the desire for knowledge and give the student a practical understanding of things he has learned, and being in the nature of a vacation he would return to his studies with renewed energy. No, because many would not return to complete the college course."

"If a man leaves school for a year's practical work the chances are that he will not return to school."

"Would advise one or two year's practical work following the Sophomore year."

"Well to advise, but not to require such a step in college course."

"Two years at least would be better."

"Nothing would be more helpful before the completion of a course than a good insight into the practical, as well as the theoretical."

"Yes, perhaps two. Don't graduate too young."

"Yes, indeed, say two years of it, and preferably before entering college."

"Desirable, but of doubtful value if made compulsory."

"No. A fellow can get a pretty good start by working in vacations. If he leaves at end of year it breaks into his work."

"Majority of men would not return to college after having one year in practical work. If they did return they would benefit greatly by the practical experience."

"It would be very well for a student to get a year's practical experience before completing his college course if he had a real good opportunity. The course of work however, given in our leading technical colleges and universities is well fitted for the student. He obtains a practical knowledge of the subjects he studies from the shop work, the physical, chemical, and mechanical laboratories and Testing Departments."

"Yes, provided the student was forced to complete the college course "

"If the year of practical experience is taken before the college course it would be of advantage. I do not think that the college course should be split in two by other work."

"I think the colleges could hardly make such a rule without often working hardship on certain students. That such course would be desirable in most cases is true."

"It is my judgment that this is advisable. A young man should take the practical training in addition to his technical studies and mingle them together as much as possible, so that he knows how to put in force and effect the result of his studies. On the other hand, it gives him a practical demonstration of his studies—he knows the result and what can be accomplished. I no not believe it a good plan for a young man to enter school, and from there to college, spending all the time in study up to the time he is twenty-one or twenty-two years of age without any practical training. Such men are often pushed aside as over-educated, technical men, who are of little worth to the practical public. They should spend at least one-half of their time in practical work and defer their completion of the college course until they have reached an age of good judgment and maturity, so that they can absorb and realize the importance of their last years of college work. This in my udgment would make the best men."

"Yes, because then one finds out to what studies he should apply himself the most and shows him what is the essential things to know."

"It would be an ideal condition, but not practical. Students would lose habits of study, and in very many cases would not return to school, and hence their engineering careers would be crippled."

"Theory alone never made an engineer, nor did one year's practical experience. However, it would help."

No. Leave it to the individual."

"Not if it interrupts the work at the college. Most polytechnic schools give practical shop work, which is nearly if not quite equivalent to a year's work."

"It would certainly have some great advantages."

"I think it would. I also think it advantageous to get the rudiments of a business training."

"Not if the student can get practical experience during vacations."

"A year's practical experience before completion of a college course would undoubtedly be an advantage. A young man of the right kind of metal would spend his summer vacations in practical work, even if he had to pay for the privilege."

"I think not. A year's experience under ordinary instances will hardly permit a man to get well started, and continuity of work at college and afterwards in practical experience is desirable."

Question No. 5.

Would not the larger companies consult their own interests and the interest of the art at large by offering an apprentice course open to college students between their Junior and Senior years?

"No. This should be between the Sophomore and Junior year."

"It is very questionable, because students as a rule are not prepared to enter testing laboratories after their Junior year."

"I think this plan would, in the long run, produce a better class of men than the present system does."

"Their doing so might be in the interest of the art at large, but hardly to their own interest."

"I cannot say in all cases this would be true. In the laboratory and in the erection department such assistance could be employed to advantage and oftentimes in the operation of plants employing such talent as helpers or assistants. There is no question but that the art would be greatly assisted by such practice, but the fact that the student as a rule has in mind the fact that he is simply working out an apprenticeship, does not in all cases lend the inspiration desired where regular employment for advancement is the aim."

"No. Factory organization would not benefit. Students would not profit enough to compensate for breaking into the routine of their college course."

"A large factory might do this, but otherwise it would not pay to bother with it."

"As to larger companies consulting their own interests by offering apprentice courses to students, our Company has for a number of years back employed, when possible, college students during their vacations. This enables the company to see what kind of young men they are liable to get to fill the ranks as the time goes along, so that when a vacancy occcurs and a young college man is offered for the job, it is known pretty well how he is going to 'pan out'."

"I do not think manufacturers should bother with students during their Junior and Senior years Students should obtain their practical knowledge at such time in practical construction and learn what they can from local railway and lighting plants."

"I think they would if students would afterward go back and finish their Senior work."

"Would not consult their own interests, except that they would benefit by the improvement in quality of men turned out at end of Senior year."

"Better between Sophomore and Junior I think,"

"No, as to their own interests; yes, as to the interests of the art.

"The larger companies are not taking apprentices or students from motives of philanthrophy, but in order to have their pick of a large number of technical experts. Hence they would not take students whom they could not keep permanently with them if they so desired."

"Of art at large, yes. Their own interests, no, for students talk too much and competition demands some secrecy about machinery while being developed."

"'The interest of the art at large,' yes. 'Their own interests,' yes, under suitable conditions covering the subsequent service of the apprentice."

"No. Continual, uninterrupted progression is the keynote to success. Any plan which would cause a student to interrupt for a year his college work would be most lamentable. On the other hand—his first year with a large manufacturing company would merely serve to give him a very rudimentary knowledge of what he had to accomplish, which requires on the part of the manufacturer expenditure of patience and time, as well as money. A large portion of this would be spent in vain if he remained but one year and then went back to school for the rest of his course."

"I do not believe it would be a paying proposition under exisiting shop conditions."

Question No. 6.

In the light of our present experience, and under existing conditions, what course would you follow if you had it all to do over again?

"I do not like engineering work, but like the engineering knowledge as applied to patent law. I would therefore devote the college training to a combination study of Law, English, and Science, with particular attention to electrical drawing and design and also chemistry."

"Same as I have, only dig harder when at college and later also."

"I would take the college course straight, spending one or two vacations in construction work, then go with one of the larger companies for three or four years in testing and construction work, and then take a year's post-graduate work."

"I would get my technical course early in some school where I could be in contact with and imbibe as much of a literary training as possible."

"College, practical work in summer if possible, and if not, apprentice course afterwards. At least two summers in some commercial business, learning office methods and also how to approach men in business life."

"Get all the general education and practical experience practicable before taking up the technical course; then make the most of that."

"Would connect myself with some large concern if possible for two years following Sophomore year, then finish college. Then return for a time to some large concern and get experience and prestige, then look up best opening possible.

"Just as I did, i. e., a few years' practical work interspersed with the college course, followed by a term in the testing department of one of the large electrical concerns.

"Mechanical English, with electrical courses taken as specials.

"I would do just about the same as I did before, namely, get a good school education, then serve an apprenticeship in some suitable shop, acquiring theory in spare moments, and then go to college."

"Take the college course, and get all the practical experience during vacations I possibly could."

"Work harder."

"Would enter testing department of large company immediately after graduation from college."

"I should enter the employment of one of the large electric manufacturing companies to gain experience. Having gained which, I should connect myself with a young and growing concern and try to secure an interest in the business."

"Take a general engineering course, supplement with a brief law course, get into the commercial side of the business, and aim to be a 'captain of industry.'"

"Take an M. E. course with as much elective work in electrical and civil engineering as possible. Spend vacations with a surveying party and in a shop. Extend course to five or six years if necessary to get the amount of work stated."

"Take a university course followed by the practical experience in the line which I specialized in at the university. Every young man should as early as possible decide exactly the field of his future labors and in addition the exact department of that field which is most congenial to him and direct his education along the lines that will be of future service to him."

"Make the utmost of my opportunity for advancement in a broad way, and apply as much energy and vigor as is consistent with good health and contingent circumstances."

"Do as I did before: Make the best of every opportunity as it presents itself. Be an Individual."

"I should qualify the training I have been through by a course at the very best technical college I could find on earth, but I would not give the praotical experience I have had for all the '$X+Y$' I have ever been up against."

"Think I would do about the same, excepting I would spend at least two years in machine shop and on outside work—repairing and the like."

"Would not leave college until I had a very thorough training in mathematics. Would spend some time in operating work and then go into the draughting room and stay at least two years. Then into either the operating or business side."

"I would recommend a young man to take the regular technical course in the branch of engineering he intended to follow in one of our leading State universities or Eastern colleges, and to follow this with at least one year's work in the testing department of some large manufacturing company. Six months or a year of work in the draughting department, would be a very valuable fitting for work either as consulting engineer or in connection with any manufacturing or central station or railway work."

"Mechanical and Electrical course in Technical School. One year at practical work, between Sophomore and Junior year."

"I would take two or three years' practical work before finishing the college course."

"I would prefer some practical experience in the line of my chosen profession, either before or during my college course?"

"I would take a thorough course in civil engineering and supplement it by a couple years post-graduate work in electrical engineering."

"I would make a beginning where experience seemed the most likely to be found, and would change every time something better offered, rather than sticking in less desirable positions as many do. I would advertise myself legitimately and be more aggressive."

"Take a complete technical course and sandwich in a year's practical work before graduation."

"I would take a course in mechanical engineering and take a post-graduate course, or else during the time of mechanical engineering studies, take up electrical work, and then enter some shops and get practical experience, after which spend at least two years drafting. A man may in all probability at the end of that time be of some value to himself and others."

"A college education first. Then find the kind of work most congenial to me and stick to it."

"Same as before. Plug for the engineering degree with emphasis on the practical rather than on the theoretical, then strike out in practice along any acceptable lines."

"Would work for a year or two before entering college at any kind of engineering work. Then four years of college, during which time I would cover three years of the electrical course with extras in history, literature, and languages. Then a year of work in the special field chosen while at work three years before, at which time I would have studied the various fields. Then the Senior year and a year more at post-graduate work. If I had to work my way through college, all the better. Then go out in the cold world and prove that you can be worth something."

"Same course, except a little more aggressive."

"I would put in a couple of years with one of the large companies where I could get the largest amount of experience, regardless of remuneration."

"Take a little more outdoor exercise."

"Same broad general education from practical men in full sympathy with the active world, at college rather than High School. Finish at either. Good practical course. Finish. Then secure employment."

"Were I to begin again with an engineering career in mind, I should see to it that my elementary education was made as perfect as possible, not only in electric lines, but in the engineering lines of steam, hydraulics, mining, and other lines of engineering work with which the electrical business today is closely interwoven. After finishing my elementary education, I should supplement it with practical information gained with one of the large manufacturing companies in the line which I cared to follow. After this I should let circumstances determine whether I should continue with this manufacturing concern or start in business on my own responsibility."

"I would get with a smaller concern for a broader experience and try to progress later by promoting some enterprise of my own."

"The one I have pursued, I think. Having to rely on one's own resources, develops the faculties to a greater degree."

"First, I would keep more copious notes. Second, I would use every effort to get stock in the concern with which I saw fit to identify myself after completing my university course."

Question No. 6—Non-Technical Men.

The following answers are of special interest as they were given by the men who had never taken a technical course.

"Take a special technical course in engineering, then start with a good company."

"Get a college education interspersed with at least one year of practical work."

"Take good common and high school course, then several years at practical work, and enter a technical school knowing what points I wanted to give special attention."

"Spend all the money I could 'scrape' together for a technical course in the best college I could find."

"Save more, study more, work more—Talk less."

"Would take a complete course in electrical engineering, then take a year's work in the testing department of a manufacturing company."

"First, college education; second, go into the shop of a reliable manufacturing company; third, avoid the shelf."

"Would get a college education and then three or four years practical experience on the construction end of my profession."

"I would secure techncal training."

"Avail myself through university training of the best there is pertaining to the special art I had decided to follow. Look to my own efforts and practical experience in detail shop and otherwise to elevate me to the success I desire."

"I would, if I had made up my mind to pursue an electrical course, take a technical education, if possible, in connection with a business one."

"School, shops during vacation, technical university, drafting room, testing shops."

"Take a technical course not exceeding three years, get into the most prosperous concern possible, doing a large variety of work, and work like fury."

"Dig deeper and commence earlier."

"Apprenticeship with comparatively small concern to obtain general idea of calling. College course, during which time obtain approximately one year's practical experience. After course fit up with general knowledge and then detail."

"I would obtain a thorough technical training, interspersed with periods devoted to acquiring practical experience."

"Acquire both thorough technical and business education. Both are equally important."

"Take an electrical and mechanical course, with a year's experience between junior and senior years."

"I would work at practical work for two or three years and then go to college. Lots of time in college is wasted for want of practical understanding."

ADDENDA NO. 2.

A MOVE IN THE RIGHT DIRECTION.

Since writing the paper a letter written by a company employing a number of technical men in electrical work has come to hand. This letter was to a recent graduate who had applied for a position, and indicates the policy which had been adopted by one large company in making a careful selection of the men who are employed in even the minor branches of the business. Is the plan of careful selection disclosed by the letter not a much better one, both for the young graduate and for the company, than the other policy of hiring college men indiscriminately at less than living wages, which latter plan is often followed, evidently, with the idea of "trying out" as many men as possible. "Over a rough road the small potatoes go to the bottom" is true, but it is a poor way to sort potatoes. Better men would be turned out of colleges if it was generally understood that opportunities for valuable, practical experience would be open to the men making the most favorable showing in some such examination as indicated by the following letter:

Enclosed please find a sheet giving outline of information desired from colleg graduates. Statements may be brief, but some of the subjects should be treated sufficiently at length to give us, as far as possible, what we would get from personal acquaintance. Some of the subjects may strike you as decidedly personal, even as being none of our business, but you must remember that beginners almost invariably represent an investment—sometimes a long investment, sometimes a bad one. We have no use, as some concerns have, for beginners as cheap labor. We take on but a few each year—try to secure only the best, and then feel a personal disappointment in failure. Applications are confidential. So far as you can prevent it, let no mock modesty, on the one hand, nor egotistical vanity on the other hand, enter into what should be a plain, manly statement of your candid opinions, as to numbers 7 and 8.

The questions which accompanied this letter made up a remarkably searching examination. They are below:

1. Date.
2. Name and address, present and home.
3. College from which graduated and when.
4. Married or expecting to be soon.
5. Age, weight, height, complexion, nationality.
6. Health, past and present.
7. Habits, tastes, ideals, ambitions.
8. Disposition and temper.
9. Practical experience in engineering work.
10. Practical experience with machinery, tools, or implements.
11. Experience in any kind of manual work. Have you a trade, what?
12. Experience in supervision or "bossing."
13. Why took college course?
14. Why took engineering course?
15. Why took electrical engineering?
16. Father's occupation.
17. Have you ever worked for wages? Doing what?
18. What have you contributed toward the expense of your education?
19. Do you want work or opportunity; i. e., have you debts or obligations to meet which you must sacrifice the future for the present, or are you in a position to begin at the bottom and receive promotion as you gain experience and find your work?
20. If convenient, enclose unmounted photograph and write essay equivalent to one typewritten page, on one of the following:

"Assistant vs. Principal."
"The Art of Self-advancement."
"Obedience vs. Initiative, a Basis for Compensation."
"The Art of Executive, a Basis of Valuation."
"Egotism."
"Vanity vs. Self-reliance, a Factor of Success."
"Tabulation and Graphic Expressions in Practical Life."

Typewritten manuscripts preferred. Treat subjects in above order by paragraphs numbered as above.

The idea that "it doesn't make much difference where a man starts in after leaving college," is as wrong as the other prevalent idea that "it doesn't make much difference at what college a man gets his training—they all teach more than any man can learn." Life is too short to deal with anything but the most essential things, and every minute counts. Let the young man who wishes to get the highest rewards which the electrical business has to offer understand that he must form his purpose early, must select work to which he is adapted, must choose his course carefully, and then must *work*, WORK, WORK.

DISCUSSION.

Mr. W. B. Hale (*Chairman*)—We have all listened with great interest and pleasure to Mr. Damon's valuable paper, and we are now ready to take up the discussion. This will be opened by a few speakers who have been selected as representing different phases of the electrical business.

I will first call upon Prof. P. B. Woodworth, who is in charge of the Electrical Engineering Department of Lewis Institute, and who has had an immense amount of experience along the general line of the paper—the opportunities for the undergraduate.

Prof. P. B. Woodworth—Members of the Electrical Section of the Western Society of Engineers: I wish to thank the Chairman for calling on me to make a short statement at this particular time, as I conceive that from this time there will be a great deal of interest aroused. But, like the writer of the paper, I came to hear the discussion and not to take part in it.

There are many important things in this paper. The majority of statements are very well stated and very correctly stated. Some time ago I think I would have agreed with everything in the paper. But at the present time I disagree with the majority vote on one point, and that is the question of dropping out of school at the end of the third year, taking a year's practical experience, and going back to school for the fourth year. That to me was an ideal condition, and I dropped out of school to get a year's practical experience, then went back for my fourth year. I thought that was the ideal thing to do. But I want to say now that that last year was the most unsatisfactory year's work I had in school, and I would not advise anyone to duplicate my experience. I dropped right out of the spirit of things and never got back.

So far as the young men are concerned who are now attending technical schools, the thing they want to get hold of most is good common-sense mathematics, an ability to read current things, to be able to go out and meet the men who want their work, who want them, and to deliver the goods, and to do it right away. You probably will remember that not very long ago young men went out from school, and it took them two, three, or four years to find their field; they could not step out of school and go right to work, and there was a feeling against the college men, because it was found that when they went into a factory they were not practical. But this feeling has changed, and technical schools are sorry that it has changed to such an extent. At the present time we have difficulty in keeping the men in college, on account of the very inducing offers that are made to undergraduates. Any young men who can do the work demanded can go right out and get it—and I am going to follow the author's commercial standard and say at $100 per month. Comparing that with the time when Mr. Damon and I started out (I started at $1.25 per day) [Mr. Damon—"I worked for nothing."] I sometimes think the demand for the services of these young men is working against mechanical education. Many young men do not stay with us because there are so many opportunities of just that kind for remunerative employment.

There is nothing the technical school man desires more than the criticisms of the friends of the technical schools, and I think I recognize that there are assembled here in this audience the different elements which constitute the friends of the technical schools.

Mr. Hale—While on this general topic of education, I think we might continue a little while, and I will ask Prof. C. E. Freeman of Armour Institute to say a few words.

Prof. C. E. Freeman—I feel called upon to compliment Mr. Damon upon his treatment of this subject, which is unique almost in discussions of this character. I think it is one of the mile-posts marking the progress of technical education, since recognition is made so markedly of the value of the technical man and the necessity of taking care of him after he has completed the preparatory work of some technical institution.

Incidentally I will say that it is almost an inspiration to form a union to suggest what the salaries of the professors should be; and while on this topic I might add that the question of salaries involves an important idea in connection with technical education. As Mr. Damon conclusively shows, that branch of the business dealing with the instruction of electrical engineers is the most poorly paid. This state of affairs has resulted in a constant shifting of the forces of instruction at nearly all institutions giving this kind of work. The management of these institutions recognizes the cause, but replies that it is not in competition with industrial concerns when it comes to offering remuneration for a particular talent. The fact remains that they are in competition, whether they wish to acknowledge it or not.

Technical schools are brought closer to the commercial world than any other class. The teaching staff must not only be able to teach the scientific principles of the various subjects, but must also appreciate and demonstrate their economical and commercial significance. Because of these latter qualifications, the technical instructor becomes of immediate value to a commercial concern. If these particular abilities which a successful instructor must possess are alone sufficient grounds for commercial concerns to offer him inducements that justify him in leaving his work as a teacher and entering some other field, it is obvious that the kind of men, before all others, needed by an educational institution has been allowed to leave. No competent business man will permit conditions whereby the personnel of his staff is constantly being changed, if he hopes to reach any degree of success. I think the day is not far distant when the business competition between technical schools will cause the management of the same to appreciate and act upon this fact, and the school that is the first to do this will gain a distance on its competitors in the race for supremacy that will require years of persistent effort on their part to recover.

The question of the comparative value and merits of the Correspondence School vs. the Technical College course is raised, and the stand taken by Mr. Damon is one with which I heartily agree. To those who are familiar with the work of both, the necessity of raising this question is not apparent, since all concerned admit the entire correctness of Mr. Damon's position. However, when we call to mind the alluring advertisements and fervid testimonials that have been associated with certain correspondence work, and it is remembered that young men are continually forgetting that there is no royal road to learning, it is not only a privilege but a duty of those in positions to know to point out the pitfalls. In this connection I would like to impress upon young men who are taking correspondence course in engineering, that the ability to answer questions that are already answered does not constitute one of the essentials for successful engineering work. One of the reasons for making this statement is that I happen to know of an incident that occurred some time since, where a young man, in answering the questions in his instruction paper, grew disheartened with the tedious process of writing out certain paragraphs in the instruction paper in answer thereto. He concluded to abbreviate, and for each subsequent question wrote, "See Section A, Page X." That young man was wasting his time, money and opportunity.

The question is raised in regard to shop experience. By shop experience I mean not only the mechanical shop, but the electrical shop, so to speak. Unquestionably the shop experience is a good thing, but I hold with Prof. Woodworth, that if this shop experience must be obtained by interrupting the college course, the danger that he pointed out from his personal experience is very likely to follow. As you probably know, the German scheme of technical education requires that experience of this kind be obtained outside of the institute, and usually before the student graduates. As a result, a rest would be obtained in a mental way, and the experience could be sandwiched in very nicely with the theoretical work, which is the prime function of the college course.

The reason for the shop experience prior to graduation is that it may enable the student to more thoroughly appreciate the principles and the fundamental theory that he is supposed to be studying, and to give him an opportunity to investigate. The shop experience after graduation is a much mooted question, but that which is offered by at least one of the large electrical manufacturing companies appeals to me as a very excellent opportunity for at least eighteen months or possibly two years after graduation from any of the first-class technical institutions. The young man who goes through such a course should recognize it as a post-graduate opportunity,—use it as an opportunity for education, and not expect so very much out of it financially.

It seems to me that the young man who has spent four years in a college course cannot expect himself to be a thoroughly prepared engineer. He must consider that he is to continue preparing for a number of years, and that the opportunities offered, it would appear, in some of these large commercial institutions constitute a most excellent post-graduate course along these particular lines. On page 6 Mr. Damon refers to the fact that there seems to be more openings for a man without college training in the telephone field than in any other. This is quite true. In fact, these openings are of such a character and so numerous that many of them find that the most likely future for the undergraduate who has no pronounced proclivities in any particular field of electrical engineering would probably be found in the field of telephone engineering. This is being recognized at Armour Institute by the establishment of a four-years' course in Telephone Engineering that shall parallel the course in Power and Lighting.

Mr. Hale—Prof. Freeman has referred to the fact that the opportunities for a non-technical man—one not a graduate of a technical institution—are probably greater in the telephone engineering field than in any other. We have with us a telephone engineer of large experience, and he is, I am sure, qualified to speak to us on that question. I refer to Mr. F. R. McBerty, Assistant Chief Engineer of the Western Electric Company, who will tell us something about the opportunities for inventive ability in the telephone engineering field.

Mr. F. R. McBerty—I am requested to speak of the class of electrical experts, and of telephone engineers, some of whom have been included in that class.

Probably the most interesting fact brought out in the paper as to this class of engineers is the large percentage of men without college training who would be regarded as successful. I wish to suggest an explanation of the fact and a deduction from it.

The development of the telephone business covers a period of about twenty-five years. Throughout the greater part of the period the requirements for telephone service have not been formulated and little data has been available from which to generalize; it was necessary to develop apparatus fitted to the needs of the service, and the business was sufficiently profitable to permit frequent changes of apparatus and to require no very high degree of economy in operation. The condition was one which called for imagination, good judgment, shrewd guessing and familiarity with actual conditions. The inventor has occupied a very important place in the art as it developed. A survey of the engineers now occupying the most important places in the telephone business shows from the total number of sixteen, ten who have had no college training;

of eight of these men, who are over forty years of age, two only and of the remaining eight, four had college training. I count thirty-four inventors whose work has contributed to the greatest extent to the advance of the telephonic art during the period of development. I lack information as to the preliminary training of eight of this number; of the remaining twenty-six, twenty-two were without college training, while four were graduates of colleges. The aggregate number of inventions patented to the thirty-four inventors is 1,315; of this number 1,053 were contributed by the twenty-two men without college training, and 167 were contributed by college men. It would thus seem that the college-trained inventors were not only greatly outnumbered by the others, but were also less prolific. In my opinion this record of patents may safely be taken as an index of the practical and valuable achievements of the different inventors.

In the electrical business, particularly in telephony, every important advance in the construction of apparatus is represented by a patent. An examination of the patented inventions under consideration shows that the quality of inventions is by no means in inverse proportion to the quantity, but that a fair estimate of the importance of their achievements would produce substantially the same alignment of the twenty-six inventors with respect to the matter of college training.

The indications of these statistic are supported by present observation. Selecting from about twenty of the younger telephone engineers those who are conspicuous for inventive ability, they are found to be four in number, all but one whom have had no college training. A cursory examination of the important inventions in the field of electric lighting and general electrical practice would seem to give about the same results; but I have not at hand the information to speak with any accuracy on this point.

The terms "technical" and "non-technical," under which Mr. Damon has classified engineers, may mask the real situation. It must be apparent that these so-called non-technical engineers who are successful in the same field with the technical men possess practically equal technical knowledge, but that they have acquired this adequate knowledge and training through their own efforts. So far as my observation goes, these self-trained engineers began early, studied hard and worked hard; they developed the inventive imagination and the ability to guess shrewdly through contact with actual conditions, and acquired good judgment through their own failures. They, therefore, were fitted to the conditions and they survived. They are receiving large incomes because their work has been valuable.

The electrical reactions and phenomena involved in telephony are more complicated than those involved in electric light and power work, while the forces involved are much feebler and more difficult of accurate measurement. The most refined mathematical expressions developed for power and lighting apparatus are only roughly approximate for conditions in telephony. During the period of the development of the telephone industry, light and power engineering has been reduced to a science, mathematical generalizations have been made available covering the greater part of the field of applied phenomena, and great quantities of extra data have been collected. By reason of the difficulty of providing such statements and such data in telephony, telephony still may be characterized as largely an art rather than a science; but it is approaching the condition of a science, and it is probable that a few years hence not only the electrical phenomena, but such other matters as the best distribution of conductors, the probable distribution of stations, the probable effect of rates, etc., will obtain mathematical expression. Further, at the present time the available apparatus appears to be well suited to the requirements of telephone service, so that radical invention is not essential, and profits have diminished so that the refinements of construction and operation must be looked to in the interests of economy. The field is thus a fertile one for the technical graduate, equipped with classified data and trained in mathematical analysis; and I look to see him occupy it as he has that of power and light engineering.

The inventing is by no means all done in the electrical industry, however. If, as would seem to be indicated by the facts about inventors which I have given, self-training tends to or college training prevents the development of the inventive imagination, the college course is not yet perfectly adapted in kind for the complete education of an engineer. It is a matter of statistics that inventive activity begins very early, before twenty. It may be that during the years spent in acquiring classified data and formulated methods in college, other faculties of the mind are developed at the expense of inventive imagination; it may also be that the technical graduate, having spent after graduation the years necessary to get in touch with the particular conditions of his practical work, is too old for radical invention. I believe the effect is due to both causes.

I therefore would suggest the query whether something should not be added to the college training to develop inventive ability in the engineer?

Mr. Hale—Mr. Damon has shown us curves representing the material value of the engineer, for an engineer must receive a salary like anyone else. He has to live, but his whole aim in life should not be to increase his salary, or even to get a salary at all. Engineering science in itself and the pleasure of working along engineering lines should constitute his chief reward. To appreciate this fully he should be an optimist. In fact, to work cheerfully for a small salary it is absolutely necessary to be an optimist. Now, we have with us tonight the exponent of optimism—a man who is an engineer and an optimist—Mr. S. G. McMeen, who has something to say to us.

Mr. S. G. McMeen—I do not know what I have done to merit this introduction. Several of us have said that we came here to listen to the discussion only, but I came not only to hear the discussion but to look upon, in the flesh, the man who has contributed to our art and to our science this now-to-be classical contribution upon a matter which comes so nearly home to every engineer. While Mr. Damon says the dollar is not the final measure of engineering, still it is inclined so to be taken by those outside—by one's friends. There are other measures. However, I may say that in this respect I plead guilty—or "point with pride," as you like—to the fact that during most of the years I have been at it, I have not often considered that side of the question. I do not point with pride, but I will frankly confess with what shame you may think is necessary, that I did not think of the dollars except at occasional intervals, when it seemed absolutely necessary to have them in order to live. Dollars are necessary, but I, in common with most of you, have done the thing for the joy of doing it, chose it because I liked to do it most.

I cannot claim to indorse absolutely all that has been said in the paper and the answers that have been given, but must take this opportunity to indorse what has been said about leaving school to get a year's practical experience and then going back; not because it is not a good thing to get some early practical training, but because of the breaking of bonds and the interruption of one sort of thing to inject another. The theoretical training is going to be disjointed, and I think it is better to get the gain of the one at the expense of the less-important other. I want to indorse almost all that Mr. McBerty has said, which I can certainly substantiate. I am very glad that we have that contribution, because there are not many places where we could go to get it.

The thought that Mr. Hale's introduction suggests to me comes very close home, because an important thing in the life of a man—and that is the greatest thing in the world, unless it be the life of a woman—is that the training a man gets in the environment of a school of any sort is one he does not get in any other way. It must be good for him if it is good training, and bad, if bad training. The "little red school house" education is one of the great things that mark the civilization of our country. If education is a good thing, it is a good thing to get it in the schools if you cannot get it in any other way.

Independent of the station he may occupy in life, independent of the dollars his practice may bring him, the engineer should work for the joy of doing it, for the pleasure he gets out of it. To work on that basis is a good thing for the man himself, because all the time he must live his life, and to live his life is the most important job he has.

I submit that the man who has some sort of a college training, supplementing his ordinary education, has a little better time in the life he lives than the man who has it not. I may be wrong, and may be on both sides at once, but it seems to me the college man enjoys the education he has and wants to keep it up, which looks like a proof that there is something in it after all.

I submit, also, that if a man does get a technical school education, it will fit him all the better for his engineering career, even though it may disqualify him as an inventor. If the latter be true, however, I am sorry.

I submit that education helps a man to enjoy his life, and if he enjoys his life and is happy, he fills a public necessity as he goes through the world. A man that gets out of his life all that he can is a public benefactor.

Mr. Hale—We are having with us tonight, gentlemen, a distinguished guest, and while we are on the subject of optimism I might say that we have asked him to talk on the future that exists in this country for the young engineer, and he has very gracefully consented to do so. The gentlemen I refer to is Dr. F. A. C. Perrine, President of the Stanley Electric Manufacturing Company.

Dr. F. A. C. Perrine—I wish to compliment you particularly tonight on the very thoughtful paper which Mr. Damon has presented, in which he has presented himself as an example of one who must necessarily become a successful engineer, because to my mind, what we need most in training and in life to make a success is thoughtfulness. This discussion has developed into a discussion of college training, and of what school work is best for the man's success in this world. I have seen a good deal of school work of all kinds, have been connected with a college, and associated with a great many students, and after it all I have come to the conclusion that it is more than the average full grown American man can do to spoil the average American child. It has been tried in every way possible. At the same time I do not wish to be understood to detract in the slightest from the importance of college education and technical training, because I believe thoroughly in it. I am glad to see that 80 per cent of the most successful men agree that it is absolutely essential. I do believe that the ideas brought out in the fourth question, in which fifty per cent of the answers were to the effect that the college training should be broken by practical training, is contrary to the spirit of concentration which Mr. Damon considers one of the points for success. I am glad to hear Prof. Woodworth and Prof. Freeman agree with me. They drew attention to the matter from the standpoint of the college training itself, but I wish to emphasize it from the standpoint of success of the man in future life. Not only does the intermediate year in college work break into the college work itself, but it breaks into the man's practical work. One of the principal things we have to get for success in this world's battle is a reputation. A man leaves college and begins where he can. He perhaps has some influence and gets his position in that way. Perhaps he takes one of those positions with an engineering manufacturer, or perhaps he takes the first job that comes along; but however that may be, he gets success only by reason of the reputation he earns, giving him opportunities to show what is in him, and that last year of college work, coming in between the first and second year of his practical work interferes with his ability to gain reputation successfully.

Another question that has been brought up, is the value of life work as measured by money. I agree entirely with Mr. McMeen that money is not the only measure which should be applied to success in a life's work. But as a man gets along in life, if he is not earning enough to support himself, he is a failure; he is not taking his place, because the world is paying him if he *is* taking his place. But that is the last way the beginner should look at the matter.

In my college work, when a student asked me whether I would advise his entering the engineering profession, and followed that up with a request to know how much he would get out of it after a couple of years, I would always advise him to go into the dry goods business, because the returns are more rapid.

Only one thing should lead a man into the engineering profession, and that is love for the work, for if a man has a love for his work, he will do it well, and unless he does it well he will not be paid. If he does it well he will be paid. So the success of those hundred men that were selected by Mr. Damon, who are all well paid men, is due to the fact that those men entered their work because they liked it, and were successful in it, and as the result of liking it, it carried them along, and they were paid by it.

Just a word more on the question of thoughtfulness in work. It is the hardest thing to get. Whether you take college trained men or men that are not college trained, successful men are those who think about their daily work.

There is one thing that Mr. Damon has not taken up, and that is the difference between the literary and technical college. The simple "rule and thumb" methods do not develop thoughtful men. There I have found the principal difference between the college trained men and men without college training. Take the men in the shops—they are as a rule the men who have not a college training, and they are not as a rule thoughtful; the trained man is. The training which teaches a man to think about his work is the training we need.

Mr. Hale—When Prof. Perrine commenced his remarks he referred to the fact that many parents were trying to spoil their children by attempting to choose a course for them. A few days ago I was discussing Mr. Damon's paper with a prominent engineer of this city, and he has some views which are unique and which open up an entirely new phase of the question. As soon as he mentioned these views to me I made him promise to be present tonight and say a few words, if possible. He was rather reluctant to do so, but finally consented. I will ask Mr. Ernest P. Warner, of the Western Electric Company, to develop that phase of the question.

Mr. E. P. Warner—Mr. Chairman and Gentlemen: Prof. Freeman, I noticed in his remarks, touched somewhat lightly upon the phase of the subject I have in mind—that is, the natural aptitude of the child. I have had occasion, during my long experience, to keep my eye on and watch the development of the young men who were growing up around me, who are getting way ahead of me and who know things I can never hope to know. It has interested me greatly to watch these boys develop and to note how the natural aptitude was exhibited. Two young men, with equal opportunities, who, to all appearances, started with the same chance, the same kind of a push, and who were perhaps supplied with an equal amount of "motive force," so far as help from outside sources is concerned, but one would far outstrip the other, and then the question would come to my mind—why? It was usually very clear to me, and was simply a matter of natural adaptation, natural aptitude for the work, thoughtfulness and love for it.

In connection with my own experience I will say that I started in at a very moderate salary, without any college education—(there were no colleges in those days where technical education in our line was to be had). I remember that I was so interested in my work that I was constantly thinking about it, even at home evenings, and my wife used to accuse me of thinking more of magnets than I did of her, and said that that sort of thing must stop. Nevertheless she often caught me working out problems on a piece of paper, or trying to get up some new scheme. She finally gave up her efforts and said that probably the best way to cure me was to let me alone.

As an illustration of the point I am making, I knew of a young man not long ago whose parents had mapped out for him a path. They wished him to become an engineer. His education was conducted with that in view, and he was about to be sent to the Chicago Manual Training School. His parents asked me what I thought about the matter, saying Johnny does not seem to like it. I asked them what he did he did like, and if he showed a liking for any one thing over everything else. They said yes, he draws pictures. They showed me some of his work; it was free hand perspective drawing of no mean order. I told his father that it did not seem to me he was going to make a good engineer, and that the inclination was clearly toward art. His father replied art does not amount to anything; it is something nobody makes much out of now-a-days; he would not be able to make much of a living. I disagreed with him and told him of a number of persons earning good salaries who had established good reputations as artists, not only in the higher lines but in actual business, such as magazine work, and lines of that kind. They thought the matter over seriously, with the result that Johnny was allowed to follow his natural bent, and I am glad to say he is making a success.

I think the Professors in our colleges would perhaps be doing a great favor to the parents if, instead of taking a boy through for so many dollars and giving him his course, they would in some cases say to the parents, "this boy will never do anything as an electrical or mechanical engineer. Isn't there something else he would prefer?"

Parents think a son will make a good engineer, just as some parents think their son will make a good minister. I have listened to a sermon by. such ministers. I should be very glad to hear from Prof. Freeman on this subject, for I presume he has given it a great deal of thought.

Prof. Freeman—I am very glad to have an opportuuity to enforce that idea. I thoroughly agree with Mr. Warner, and with Prof. Perrine, that aptitude is a true requisite for success in work. Too often we see a fond mother or father who get their ideas of engineering proclivities from the fact that the boy has been interested in choo-choo cars, or the idea that engineering is a nice clean job and a proper thing for Johnnie to take up. It is the policy of the Faculty at Armour Institute to carefully sort over the various members of the classes—particularly the freshmen and sophomores—and the question is asked of all instructors having charge of those men, "Do they exhibit an engineering bent? Have they an engineering aptitude?" If it is agreed that certain students seriously lack an aptitude for engineering, incidents naturally arise whereby they are induced to change their course. I think that not only justice but duty demands that instructors shall insist that a young man take some other path through life rather than the one which surely will lead to failure.

Mr. Hale—An engineer possessing the aptitude and ability described by Mr. Warner is always competent to design satisfactory electrical apparatus; but to be a commercial success this apparatus must be sold. Now, the old plan was to put the finished product into the hands of salesmen who more often than not knew little or nothing about its construction. The new and better way, however, is to have in charge of the sales department a skilled engineer who is as thoroughly at home in the manufacturing as in the sales end of the business. I will ask a gentleman occupying this very position with one of the large manufacturing establishments, Mr. A. L. Tucker, to tell us something about the opportunities for the sales engineer.

Mr. A. L. Tucker—I have enjoyed this meeting greatly, and I think the rising generation ought to be congratulated upon having presented for discussion an article of the importance which this has grown to be. I also think that great good could be derived if this paper, with its discussion, could be put into the hands of students who are now or who will soon be in the preparatory schools or academies throughout this section of the country.

I would call your attention to the opening sentence of Mr. Damon's paper, which perhaps might be called the integration of the whole subject. Because this business is complicated, it requires of those who would partake of its benefits the most careful and complete preparation. The preparation of the soil is always a difficult one. Probably the industry of farming has been longer known than any industry with which man has had to do, and yet there have been greater strides in the last thirty or forty years in the farming industry, because of the advanced knowledge of how to prepare the soil, coupled with the means for doing it, than in the previous history of the world. The question of preparation for business, as complicated as the one before us tonight, is therefore worthy of the deepest and most careful consideration.

The electrical engineering science started with the Leyden jar, the horseshoe magnet, and the primary battery, but it has now developed to such proportions that it seems to be bounded only by the symbols of higher mathematics and the letters of the Greek alphabet. The broadening out of the business has brought with it larger responsibilities, and the electrical engineer of today must not only have accurate knowledge regarding electrical science, but of all the allied sciences as well, while the requirements of the salesman are such that he must be able to appreciate the language of the engineer, to read his thoughts, and to catch his spirit; in other words, he should be an engineer as well as a business man.

With this development has come greater and more numerous opportunities, for as the base of a structure is enlarged the development is in proportion to the square, and as the structure is carried upward to its highest perfection, another element is taken on, and the development is in proportion to the cube. If a business may be likened to the growth and development of a structure, the general rule follows that opportunities for success are always in proportion to the enlargement. This rule would seem to apply, for the reason that the demand today is greater even than the supply, but the demand is for that class of men who have a fundamental knowledge of the science of the business, who know how to think and to put their thoughts into action; coupled with a sterling character that is as true as their compass and as inflexible as the laws with which they work.

I agree with the previous speakers on the question of dividing the concentration of thought of the student through his college course. It seems to me that it would be a great mistake to encourage a student to leave his course in the midst of it and enter a new field in a manufacturing establishment, with a view to re-entering the college and taking up the work where he left off. The danger in pursuing such a course is that he loses a good deal of his previous college training, while what knowledge he has gotten in the shop at practical work is poor compensation for his loss. On the other hand, manufacturing establishments, while they may be termed institutions, must be distinguished from institutes. Manufacturing establishments must necessarily perform certain things, and must have men whereby to perform them, and it is my judgment that officials in such establishments would be very loath to employ students from any college who were to remain with them but a limited time with the view to returning to their college course, perhaps never to again re-enter the establishment. It seems to me we ought to encourage students to concentrate their efforts, as uninterrupted and concentrated work is the keynote to success.

Mr. Hale—After a dynamo or motor, designed by a designing engineer, has been placed in the hands of the sales engineer, of whom Mr. Tucker has told us, he sells the machine to a large operating company—the Chicago Edison Company, for example,—and I will ask Mr. Junkersfeld to tell us about that part of the business.

Mr. P. Junkersfeld—Like many of those that preceded me, I came here to listen rather than to talk.

The remarks made by Prof. Woodworth, and Mr. Damon, regarding their early start, remind me somewhat of mine, and while my experience was a hard one, considering my sore hands and tired limbs, I look back on that experience with a good deal of satisfaction. I am also carried still further back to my college days, to the observations I made at that time and since then, in coming in contact with a large number of young men. This observation and contact has impressed me with one point that has been brought out, and that is the inaptitude shown by some young engineers for engineering. It was also shown that our technical institutions are, to a certain extent, doing something to correct such mistakes, but I do not believe all that work should be shouldered on to the professors. I believe a great many parents and a great many relatives make the mistake of encouraging a young man to go to college too early in life. He often goes at a time when he has only a hazy notion of the qualifications for, or the sacrifices to be frequently made by the succesful future engineer. Also instead of breaking into the college course for a year or more, he should, in my opinion, get as much of that so-called practical training before going to college as possible. It helps him to better comprehend his work.

Another point I want to mention, and that is the importance to engineers, particularly those employed by Central Station companies, of having a certain amount of mechanical (and particularly steam) engineering experience. An electrical engineer employed by a Central Station company is severely handicapped if he has not a good working knowledge of steam engineering. It does not matter whether he acquires that knowledge, after or before his college course. He should know in a broad way the economics of engineering; have a good idea of business law, be able to make proper valuations, to judge of the productiveness and probabilities of given investments to bring returns. He needs a knowledge of men as well as of materials. Some shop, station or business experience, even though in a small way, is a great advantage for any young engineer.

Mr. Hale—While speaking of power apparatus and power machinery—electric power—I will ask Mr. Sessions, of the Stanley Electric Manufacturing Company, if he will not say something on this subject?

Mr. E. O. Sessions—You have asked me to speak on rather a hard subject offhand, as it covers such a multitude of things. I would prefer to speak on the education of the sales engineer. Mr. Tucker has told us something about these men. The make-up of the sales engineer is necessarily that of a construction man, and the construction man's education should necessarily be a very technical one, as he handles perhaps everyday, propositions that are about as broad and as technical as can possibly be made. This construction experience in my case embraced a high school education, supplemented by a two years' technical course and a four years' course in a large manufacturing establishment. I can only say, in regard to the technical course, that I am very sorry I did not have the other two years, and if I could possibly break off now and take it I would do so.

I should advise that the beginner take a manufacturing course in a large electrical manufactory of some sort, and supplement that by about two years "on the road," and during that time that he gain further knowledge of law, good manners, tact, concentration, and an ability to get at things. I believe that these are the essentials for such a position.

Mr. Hale—Referring to the table in Mr. Damon's paper, showing salaries received for different kinds of work, I notice that the salary of the consulting engineer is $6,400. I am going to ask Mr. Kempster B. Miller, the well-known telephone expert and consulting engineer, to tell us how he makes so much money.

Mr. Kempster B. Miller—My entrance into the field of consulting engineer has been made public just a little before I expected it. However, I am very glad of Mr. Hale's introduction.

I will disregard Mr. Hale's reference to making money, for Mr. Damon has said that this is a questionable measure of success. I will point out one qualification for success, which, it seems to me, has not been brought out with sufficient emphasis this evening. This qualification is the ability on the part of the young engineer to weigh efficiency *per se* against what may be called commercial effectiveness. It may take a good man to design a machine for a certain line of work, having, say, 85 per cent efficiency. It takes a better man to be able to judge whether or not a similar and cheaper machine with only 75 per cent efficiency is not, after all, the better sort of machine for the purpose. Some engineers, in their work, aim at perfection in point of mechanical and electrical efficiency, regardless of any sacrifices that may have to be made in regard to simplicity, cost, reliability, etc. The best men, however, know that it is often well to sacrifice efficiency for other qualities, and the sooner one learns to properly balance these factors the better will be his opportunities.

Much has been said, particularly by Mr. McBerty (and he knows), as to patents. Patent work affords a good field of opportunity—it seems to me not adequately appreciated—for young men of the proper turn of mind. I do not refer to the patenting of one's own inventions, for most of us are not slow in appreciating the merit of our own ideas, but I do refer to the work of taking out patents, and the work that is often required in connection with patents when they are the subject of litigation. Probably the best training for a man who wishes to become a patent attorney or a patent expert, is, after securing his technical training in a college or in any other manner, to enter the United States Patent Office as an assistant examiner. By this means he will become familiar with patents in general, and with patent law. Besides this, he will become thoroughly conversant and up-to-date on at least *one* particular art, whether it relates to electrical work or to the manufacture of shoe buttons. The salary at the start is $100 a month, not an unattractive figure for the average man to start on when leaving college. The opportunities within the Patent Office as to ultimate success are limited, but the opportunities opened up on the outside to the man who has the nerve to learn the lessons of the Patent Office and then to "make a break" in commercial life are not limited.

Now a word as to the correspondence schools. I know from personal experience, and actual intimate contact, that the correspondence schools are doing good work. I agree with what Mr. Damon, and particularly Prof. Freeman, have said in regard to the method of conducting examinations. There is the best chance in the world for a student who likes to fool himself, to obtain high marks, but it is very seldom that he will fool any one but himself. To the right sort of a man, however, to whom the opportunity of going to college is denied, the correspondence school will be of the greatest assistance, even if it does nothing more than to make him study, make him think, and write out his thoughts. If it does not do this, it is liable to improve his penmanship and spelling, which counts for something.

Mr. Hale—There have been quite a number of references this evening to correspondence schools and correspondence instruction, and I think we might devote a little time to that subject. We have with us the Superintendent of the International Correspondence Schools, Mr. L. A. Lavers, who will speak on correspondence instruction in general, its advantages and its limitations.

Mr. L. A. Lavers—When I was called up over the 'phone this afternoon and invited to attend your meeting tonight and to say a few words to you on the subject of correspondence instruction, it occurred to me to write out what little I had to say; and in that connection I am reminded of the distinguished Norman McLeod, who was once preaching in Ayrshire, where the reading of a sermon is the greatest fault of which the minister could be guilty. When the congregation dispersed, an old woman, overflowing with enthusiasm, addressed her neighbor: "Did ye ever hear anything so gran'? Wasna that a sermon?" But all her expressions of admiration being met by a stolid glance, she shouted: "Speak, woman! Wasna that a sermon?" "Ou, ay," replied the friend sulkily, "but he read it." "*Read it*," said the other, with indignant emphasis, "I wadna care if he had whussled it."

But to proceed to my subject. It was my privilege to receive an advance copy of Mr. Damon's paper, which has been presented here this evening, and, while I have not found time to read it through, I did read that clause on page 7 which refers to correspondence schools.

I am not going to question Mr. Damon's statement as presented therein, but I do want to say this, that after every college and night school now in existence has its capacity taxed to the utmost, and even after the present capacity has been doubled, and after every man who could avail himself of a college education has done so, there will still be left a great army of ambitious fellows rightfully aspiring to greater possibilities, and more who ought to be, whom not only the present correspondence schools, but double their number, will not be able to properly take care of.

But I hardly feel as though it were necessary for me to enter into a defense of correspondence instruction. That method of im parting instruction, when properly conducted, has been demonstrated a success beyond the shadow of a doubt, and the man who argues otherwise, or the man who does not know that to be the case, only displays his ignorance of what is being accomplished.

But do not misunderstand me. I do not say that correspondence instruction is preferable to a college education; on the contrary, during my connection with correspondence work I have on a good many occasions been asked whether I recommended our system in preference to a college course, and I have invariably said that if the party could attend college by all means have him do so.

But I have no sympathy with the fellow who, because he cannot for any reason attend college, will not aim to improve himself by the best means that are within his reach, whatever that means may be. Nor have I any sympathy for that maudlin sentiment we so often hear expressed, that "a little knowledge is a dangerous thing." Such a doctrine is a fallacy. Every little thing that we can add to our general store of knowledge is just so much gained, and because we cannot learn *everything*, even about one particular thing, it does not follow that we should not learn *anything*, or that the little we learn will be dangerous to us.

My contention, Mr. Chairman and gentlemen, is this, and I believe you will agree with me, that the more a man knows about a given line of work the better he can do that work, and that every little helps.

The better he can do his work the more his services are in demand, and the more his services are in demand the better salary or wages he will be able to command.

We don't any of us, Mr. Chairman, know it all, but most of us are learning something every day, and we are the better for what we do learn, and the more we learn the better.

I am not here to advertise correspondence instruction particularly, though I believe in it thoroughly, but I am going to take the liberty of saying that every man in this room ought to be a friend to correspondence instruction. Many of you I know are, and you cannot be too enthusiastic about it either. Many thousands of young men throughout the country are receiving substantial benefit from it, and more ought to be.

We make no claim to be able to inject an education into anybody, as a doctor might a little morphine, but if a student, by a correspondence method, will apply himself as he must apply himself to gain success in anything, no matter what it is, he cannot fail.

But, gentlemen, if I argued this subject with you for an hour I could not say anything to you half as well calculated to carry conviction to your hearts regarding the practicability of correspondence instruction as the one single statement that the International Correspondence Schools of Scranton, which I have the honor to represent, received from their students throughout the country, during the four weeks ending the 13th of February, 77,076 lesson papers and drawing plates, which were individually inspected, corrected, and returned. I repeat, 77,076 papers in twenty-four working days, an average of 3,211 a day.

In the face of that statement, gentlemen, and in the face of the work being done by other correspondence schools, is there a man here who can find it in his heart to say other than, God speed the system of correspondence instruction.

Mr. Hale—I think that Mr. R. F. Schuchardt has a few words to say to us on the subject of correspondence schools.

Mr. R. F. Schuchardt—I have been very much interested in the remarks of Mr. Lavers. We are always glad to hear direct from headquarters about this subject in which we are all so much interested, since so many young men are now using these correspondence courses as the ladder by means of which to climb up in our profession.

Prof. Freeman and Mr. Miller, in their reference to correspondence schools, have almost stolen all my thunder but I may be able to add a little echo, as I have recently gained some information on this subject. I want to say at the outset that I am a friend of correspondence schools. They can be and undoubtedly are a source of great usefulness to many, for all ambitious young men are not so fortunate as to live in a city like Chicago where such excellent opportunities are afforded them as at Lewis and at Armour institutes. The many letters which we see in the advertising pages of our magazines and which are written by correspondence students, telling of how they have risen from dynamo-tender to general superintendent in some three months or more, are certainly strong testimonials of the effectiveness of these courses. I am also a firm believer in this—the harder a man has to struggle for an education the more good he will get out of it—and the getting of an education from a correspondence course is not altogether a path of roses.

Several young men of my acquaintance have recently taken up correspondence instruction and as I am more or less interested in their general improvement, I have at times discussed their progress with them. The information thus gained showed me that there is some room for improvement in these courses and it emphasizes the statement made by Mr. Damon on page 7, that "a young man who will deliberately choose correspondence instruction if anything else is available is making a serious mistake." It is true the schools are comparatively young and they will undoubtedly improve with age and experience. Meanwhile, friendly criticism of their work will probably be welcomed by the management of the schools. From what I have seen it seems that in the efforts toward the financial efficiency of the institution, the educational efficiency has not had quite sufficient attention. A little more care might be taken with profit by the instructors in the preparation of the papers. Of course, typographical errors will appear in almost any work but in a correspondence course such errors are very apt to mislead students and very strenuous efforts should be made to prevent their going out. I remember seeing a statement in which a simple grammatical error made it read that the "inch" and the "centimeter" are the same thing.

As an illustration of one phase of Mr. Damon's statement, already referred to, I will cite the case of a young man who had subscribed to the electrical engineering course at a correspondence school. He had paid two $5.00 installments toward the $65.00, the total cost of the course, and had received two or three lessons which he found rather difficult. The school then offered him a discount of $11.00 if he would pay the balance in cash, and he came to me for advice. Investigation of the electrical course of the Lewis Institute night classes showed that this man could get the entire electrical course there, with the personal attention of the instructor in nine terms (three years) at a cost of $5.00 per term, a total of $45.00 if he took the entire course. He is now enrolled at Lewis Institute.

The principal failing of the correspondence courses as at present conducted appears to be that they appeal to the memory rather than to the thinking powers of the student. To illustrate—a student of a correspondence school recently applied for a position in a large central station. As a card of introduction he handed out a bunch of lesson certificates which showed him to have passed very satisfactorily in every branch of his studies. In dynamo-electric machinery he had a mark of 100 per cent and in no lessons had he received less than 99 per cent, yet he could not draw a simple dynamo nor tell what its parts are, nor had he any idea of the simplest element of a commercial electrical system. To cap the climax he then produced a letter from his correspondence school addressed "to whom it may concern," in which his aptitude for central station work, his general brightness and efficiency were set forth in glowing terms. This letter was undoubtedly written in good faith but it seems to me the "subject" should have been more thoroughly investigated before being given the blue ribbon.

Now I do not wish these remarks to be interpreted as hostile criticism. I repeat that I am a friend of correspondence schools and I am interested in seeing the men who can get a higher education only through such schools get the very best for their hard-earned money. I say most fervently, "God bless the correspondence student."

If these remarks reach the management of the correspondence schools and they receive such little attention as they may be worthy of their object will be accomplished.

Mr. Hale—Mr. Cloyd Marshall, Assistant Engineer of the St. Louis Exposition, is present this evening and will, I am sure, be kind enough to tell us of the opportunities afforded by World's Fairs and large spectacles of that order.

Mr. Cloyd Marshall—In looking about me this evening I have been seeking familiar faces, but find very few. It seems to me that speaks very forcibly of the fact that electrical engineers are coming and going. I was a member of the Chicago Electrical Association four or five years ago, and supposed I would know nearly every one here to-night, but I see very few who where here at that time.

I can well imagine, in reading Mr. Damon's paper, what satisfaction it will be to those who are younger, to look at the financial aspect as presented. I think, taking the profession as a whole, you will hardly find an average that will show so well as that, in the electrical field. I think too, that to the average young man at starting, $2,000 to $2,500 sounds like a pretty big figure, so he ought to be satisfied in the future if he is looking in that direction.

In going over the country as I do, I find a great many changes in every way; new developments in machinery; new companies springing up and old ones going out of existence, and that leads to the thought that the electrical engineer must be a progressive man; there are new conditions put to him all the time. We see that every day. For example, we have steam turbines taking the place of steam engines; that means new power house designs, etc., and tonight a gentleman has been telling me about something that will revolutionize storage batteries. And so a young man must not confine himself to a particular kind of work. Of course he must specialize, but that should not narrow him to too great an extent.

In looking over my acquaintances among college friends, I have been rather astonished that some men who were not particularly good students have made a comparatively great success in commercial work, and I have sought for the reasons. The only thing that presents itself is this, that these men who have been successful were friendly and knew how to approach men; it seems to me that personality and also the power of expression, either in writing or by word, have a great deal to do with success, and that is something which can best be done perhaps, through just such organizations as this, and the American Institute of Electrical Engineers, and others.

Perhaps I should say a word about the World's Fair. Of course there are some opportunities there, but not so many as people think. I believe we get from ten to a dozen letters a day from young electrical engineers looking for opportunities at the Fair. A few applications can be accepted, but not many. From Mr. Damon's tabulation of salaries I would recommend that not many of you apply for a position at the World's Fair, but from an experience standpoint there is nothing better. In electricity there is constant development and advancement, and every few years marks an epoch. So we must remember to keep ourselves well posted.

Mr. J. W. Mabbs—I would like to make a little comparison between the technically educated man and the non-technical. I am a graduate of the college the paper refers to as the college of "Hard Knocks," and belong to what has been spoken of as the past generation.

Some years ago I made a trip through Purdue University, and the thing that struck me the most, was how quickly those young men learn things that took me so long to learn. Right there, it seems to me, is a great difference between a technical and non-technical education. The hard knocks that a man gets in practical experience undoubtedly is a training, and it is a college course. A great many enter it, but few ever gain the senior year. The reason is, the course is very long, the knowledge is gotten by hard knocks and long experience. The young men that have college training have the advantage of gaining knowledge by the mistakes and experience of others, and they do not have to retrace the ground several times in order to get this knowledge. In that way they get over the ground in a short time and to great advantage. Those not having this opportunity appreciate it even more than the man that has it.

Mention has been made here tonight that a large percentage of the inventions come from the men that have not had a college education. I think the reason for that is that the practical training is like "the mills of the gods—they grind slowly but grind exceedingly small," and it makes a man very thorough, especially if he goes anywhere near through the course. He is better fitted to grasp the details which go into an invention than the technical man. The technical education is a great advantage, and when combined with practical training produces the highest type of engineer.

In regard to the bent of an engineer, it is a good deal the same way as it is with the mechanic. They always told me that a mechanic is born, not made. The same rule holds good with the electrical engineer. If the college man has the advantage in time, the practical man has the advantage in the ability of doing things. I remember a young man came to our shop at one time who was a graduate of a technical college, and had also been a Professor in the same college. His ability to do things was very limited. He was long on theory, but very short on practice—to such an extent that he graduated from that shop in about three weeks.

Mr. Harold Almert—The hour is getting late, I know, and some of the members getting restless, but this subject has been so very interesting that I am sorry it is not a "watch meeting." There is just one point that I want to touch on, which came to me during Mr. Warner's remarks, and that is regarding the early education.

I can remember in my early.school days that a great many of my schoolmates did not realize nor appreciate the necessity of having an education, and wasted a great deal of time. It seems to me it would have been better if they could have had some practical experience, by which they would have been shown the necessity of having an education.

Regarding the correspondence schools. About five years ago I wanted to better the conditions in a certain department, and for that reason I conducted an evening school on a small scale. I was very much surprised at the results at the end of the year, for out of fourteen employes in the department there was just one left when the year was over. They got along so nicely that they were able to take better positions. Since then I have recommended the correspondence course to those who have not been able to take advantage of the evening classes in and about Chicago, and I have noticed that the percentage of those who have finished the courses is about 1 to 10, but that *one* is certainly worth double the money that he was before he began the course. The correspondence schools are certainly doing very good work for those who cannot take advantage of the work that has been outlined here tonight.

As one interested in the work, I want to advise those who have not already done so, regardless of whatever courses they may be taking and whatever courses they have had, to put in an application for membership in the Western Society of Engineers.

Mr. Francis Raymond—It is interesting to note that President James M. Dodge, of the American Society of Mechanical Engineers of New York, on December 1st last, allotted to technical graduates an income of only $650 at the age of 22, $900 at 24, $1,350 at 26, $1,800 at 28, $2,050 at 30, and $2,150 at 32. He rated shop trained men at $675 at 22, $780 at 24 to 32 years. Trade school men receive $850 at 22, $1,000 at 24, $1,200 at 28, and $1,250 at 32. These figures would seem to leave no doubt as to the good value of technical school education.

Mr. Dodge's address reminds me that Mr. Damon's average man at 33½ years, with income of $3,440 per year, represents the potential value of $68,800 upon which he earns 5 per cent for a 50-week year.

Mahin's Hand Book rates the 4,780 general officers of the railroads of this country at an average of $3,423, and the 4,923 other officers at an average of $1,735 per year; the engine men, the best paid of all other railroad employes, receiving but $1,965, while next on the list, the conductors, receive but $1,650.

I would like to call attention to Mr. Damon's advice, that any man "will find that the electrical business is so broad in its scope that a natural aptitude in any direction can be made of use." Further, I would suggest to the younger electrical men to make a special effort to make friends in every direction, and in addition that the one necessary thing to success is "work, WORK, WORK!"

Prof. Morgan Brooks (*by letter*)—It is of course very gratifying to have such a unanimity of opinion of the value of technical training, especially from those who have missed it themselves, but this should not allow the teacher to become complacent; it should rather encourage him to try to improve the training so that it shall continue to lead in the preparation of technical men. I do not believe that any school could require definitely that a year of practical work should be inserted anywhere in the course. That would not only lead to many never finishing, as has been stated, but the uneven experience of different students would not equip them particularly well for a saving of time in a particular direction. Many have said that the the technical schools already devote too much time to shop and laboratory work. I doubt this, for whereas the strictly theoretical training is no doubt the province of such schools, the establishment of theory is much more certain if accompanied with experiment, and further the graduate must have some technical training to enable him to take hold quickly of whatever work he finds to do.

The relation of mathematics to technical education as well as to the engineer I would like to see discussed. I feel that the graduate often discards the benefits of mathematical treatment of a question, because he has been foolish enough, or not trained to realize that an exact result cannot be had from inexact data, or from data improperly applied. The lower classes in the University get an idea that every solution must be mathematically correct to an indefinite number of decimals if you please, when perhaps there may be an uncertainty of ten per cent in the given quantities. It is as absurd as to use every refinement of trigonometry in calculating the area of a field down to hundredths of a square foot, when the dimensions were merely paced off, and the angles guessed at. I have often given engineering questions in examination with intentional indefiniteness, telling the student to assume reasonable conditions where not given, and to work out a reasonable result. Sometimes also I give out unneccessary data; the boys get the idea that every item of information (as is the case in mathematical statements) must somehow apply to the question. I believe that engineers do not use mathematical analysis half enough, but that perhaps it is in part due to the method of teaching mathematics, not discriminating enough. I tell my students that they must not underestimate the ability of those who have not had the advantage of a technical education. The athlete may be overtrained, and not able to walk so far in a day as a lame man, who knows how to use his strength to best advantage. I do not think that egotism is so general a fault of the trained graduate today, although it perhaps is not the easiest thing to impart sufficient self-assurance without egotism.

Mr. A. S. Hibbard (*by letter*)—Some interesting matter bearing upon this particular question is, I think, found in the essay of Andrew Carnegie, entitled "How to Win a Fortune," in which he makes some interesting comparisons between the successes made by men who have had college educations and those who have not. He states that he asked a New York banker to give him a few names of presidents and vice-presidents and cashiers of their great New York City banks who had begun as boys or clerks. He was given thirty-six names, and it was stated that more might be presented. Among the entire list there was not one college graduate, and Mr. Carnegie states that he has inquired and searched in all quarters, but finds small trace of him as the leader in affairs, although not seldom occupying positions of trust in financial institutions. The meat of the whole matter seems to be largely within the following paragraph:

"Nor is this surprising. The prize-takers have too many years the start of the graduate, they have entered for the race invariably in their teens—in the most valuable of all the years for learning—from fourteen to twenty; that while the college student has been learning a little about the barbarous and petty squabbles of a far-distant past, or trying to master languages which are dead, such knowledge as seems adapted for life upon another planet than this, as far as business affairs are concerned—the future captain of industry is hotly engaged in the school of experience obtaining the very knowledge required for his future triumps."

This seems to bring up the point which I think we must all acknowledge, that the years from fourteen to twenty are the greatest years for learning. If they are devoted, to some extent at least, to learning that which we propose to stick to in after life and take up as a business occupation, we will have advantage over others who do not devote these years to such profitable employment.

Mr. Carnegie in his essay makes a decided exception of a polytechnic and scientific education, and points to the successes of men so educated in the steel industries, and in others, and he by no means seems to disparage a general college education to men who can afford it.

But the age limit is the particular point which I am interested in bringing out in this letter and to present the question, Is it possible for boys to so shape their course that they will get an equivalent of two or three years' hard work in the business which they expect to pursue before completing their technical education? Or, is it possible by shortening courses or by other means to get them out of college by the time they are nineteen or twenty at the most and get them at work at that time, letting them finish up some branches of their studies later on? I think it will be found almost the rule that the older the graduate is the more difficult it is to get anything out of him in the way of development when he takes up his work. There is a tremendous difference in this respect between the man of twenty or twenty-one and the man of twenty-five or twenty-six. To get a man into a technical business and to make a success of him, I think the next essentials to brains and ability, are youth and enthusiasm.

Mr. Eugene B. Clark (by letter)—The paper presented this evening deals with a subject of vital interest to the electrical profession, not only from the standpoint of the worldly success of each member thereof, but also from the standpoint of the progress of the science and art of electrical engineering. Mr. Damon has been to much pains to arrive at the data for his paper, and has so carefully and thoroughly assimilated the data which he collected, and has presented his deductions so clearly, that it seems as though, really, there is very little which remains to be said upon the subject. It is probably true, however, that we, all of us, are interested in the question of the education, not of the electrical engineer alone, but of his brethren in the allied branches as well. Were statistics gathered, the speaker believes that they would show that fully 50 per cent of the young men who educate themselves for electrical engineers eventually leave the profession to enter some other line of work. In fact, I believe that 33⅓ per cent of the college graduates in electrical engineering fall into some other line of work within two years after graduation. This is as it should be, because it is impossible for a boy entering college to know for what work he is best suited. He frequently selects his course at college because it is the same as some friend, or because his relatives, being lawyers, tells him there is no chance for a young man in the law; or, being doctors, tell him there is no chance in medicine; or, being business men, tell him that he should have a profession by all means. Having started his course, in entire ignorance, perhaps, as to what it really means, he generally completes it and thereby gets a fair start towards being an electrical engineer before he discovers the meaning of that term. After graduation, he may have the choice of five cents or ten cents an hour with some large company, or a position entirely outside of the electrical profession which will pay him much more money. If he chooses the latter course, he gives up his electrical work; if he enters the employ of the electrical company, he may not (in fact, I may say, he will not) obtain advancement as rapidly as he believes he should, and he may take an apportunity to leave his electrical work and take up something else. Even if he spends several years in the electrical work, he may become imbued with the idea that frequently occurs to all of us, to the effect that the other man's duties are easier and his prospects brighter, in which event he may leave the electrical profession.

It is to our interest that as many bright, educated and enthusiastic workers are enrolled in the force of electricians as may be secured. Therefore, we are interested in keeping in the ranks as many as possible of those who do remain. Of course, under any condition, many will fall by the wayside, but this is inevitable.

With the facts in mind, it is evident that all of the preliminary work in the education of an electrical engineer, or for that matter, of any engineer, should be made interesting. A man generally excels in that in which he is most interested. Most boys are interested in handling tools and in experimenting with batteries, bells and motors. In other words, they are interested in the practical side of electrical work far more than the theoretical side. We appreciate thoroughly that, without the theoretical side, the practical training is of relatively small value, and we know that a man's education cannot start with the practical and end with the theoretical. In order to preserve and excite the interest of the student, the practical and theoretical training should proceed together. College courses should be planned with this end in view. If a year's practical work can be obtained during the college course, so much the better. If the student has the strength to spend his summer vacations, or a portion thereof, in practical work, it will be of inestimable value to him. After graduation, if he pursues unremittingly his quest for theoretical knowledge, he is helped on his road to success immeasurably. The large electrical companies offer much assistance to their student employes in their efforts to continue their technical education, and the tendency to such assistance is increasing yearly.

Prof. Geo. D. Shepardson (by letter)—The Society is to be congratulated upon receiving a paper upon so important a subject, handled in so thorough a way by one so well qualified.

The subject is one that is ever fresh with educators, and one that must be discussed with candor. One of the most difficult tasks that meets a technical professor is to advise young men as to the best course for them to take. There is no course that exactly fits every case, nor is it desirable that all should obtain the same preliminary training. Comparatively few have the qualifications for pursuing a course at a technical school with greatest profit. The tendency is to make the engineering courses emphasize the fundamentals more and more; to give the students more thorough training in the general principles underlying practice; to train them to go to the bottom and understand thoroughly the fundamental principles involved; to train them to analyze a problem for themselves and find a correct solution. Mathematical theory is given more attention as the basis of most electrical phenomena. The complicated phenomena of alternating currents and the more complex telephone currents invite high skill in mathematics for even a qualitative understanding, while their quantitative investigation may baffle even the most proficient. This mathematical study is carried on, not for the sake of the mathematics alone, but as the basis for true engineering. The work of the school should be fundamental, giving the student a thorough grounding in underlying principles, fastening these by numerous problems from commercial practice, and by personal experiments in the laboratory. In the four years required for taking a technical course, there is so much fundamental training required that comparatively little place remains for manual training. The main emphasis should be placed upon thorough training in the fundamental reasons for things. This is necessarily so permeated with mathematics, that a young man has a hard prospect ahead unless he has a sound preparatory training in mathematics. If he is not familiar with the mathematics of the high school, or if he is not ready to secure it, he cannot ordinarily follow or even enter an engineering course as taught in the best technical schools. A technical instructor therefore frequently has to discourage young men from attempting a technical course when they have not and cannot get the necessary preliminary training. The majority of those who enter such a course fall out by the way, an average of only one-third of those who enter as freshmen succeeding in graduating. This weeding out of lazy and deficient men leaves only the cream to rise. The average technical graduate is no thermometer, graduated and given degrees without brains. He has taken a thorough course of training, has been given a strict diet on fundamental theory. He has had only enough actual experience in the laboratory to enable the average student to thoroughly digest the theory; in fact, much of the theory will remain to be regurgitated and possibly masticated and assimilated in later years.

Students should be urged to get practical experience during their vacations. Whether this comes in the factory, in the station, with a construction crew or in a machine or repair shop, will depend largely upon local circumstances. I would gladly see the factories open their doors more widely to the students for vacation work, but in the nature of the case they cannot disturb their regular work to accommodate transient apprentices. I frequently recommend students to stay out of school a full year, when they have a good opportunity to get first-class experience; in some cases urge them to stay out if the experience may not promise so much from an electrical standpoint. Such an experience will often show a student that electrical engineering is not what he fondly hoped it would be, and it may turn him into more suitable work. A good man is strengthened by such practice, and my experience has been generally that the good men will return to complete their technical training, much the stronger for the experience. The presence of these returned students with their minds matured by the practical work is of much benefit to their fellow students.

We are not troubled with difficulty in placing graduates, except the difficulty of selecting the men for the positions. For several years past, the number of inquiries for good men has exceeded the output several fold. There is difficulty in securing opportunities for under classmen to get experience during the summer vacation, although the majority of those who care to work can secure jobs with construction crews or in repair shops.

Our work is largely with those who are prepared to take a thorough technical course. The frequent inquiries from those who lack either the preparation or the brains necessary for such a course, emphasize the need for first-class trade schools which will give the elements of sound theory with a larger amount of shop practice. There seems to be a field that neither the universities nor the correspondence schools can fill with entire satisfaction.

CLOSURE.

Mr. Damon—The lateness of the hour is sufficient excuse to be brief in closing. I thoroughly appreciate the spirit in which the paper has been treated this evening, and wish to thank those who have contributed to the discussion for a very enjoyable and instructive evening. I am sure that all of us feel inspired to take up our duties on the morrow with more enthusiasm and with a resolution to do our work a little better than we have done before.

How true it is that it is not so much the opportunity that makes for success as being ready when the opportunity comes, and I know that those who are in the electrical business feel that the opportunities are all about us. In this connection, I am reminded of the legend told so many times by Russell Connell, entitled "Acres of Diamonds." You will remember that the story tells of a man who had become tired earning his living by farming, and in an effort to get rich quickly, sold out his lands and buildings and started out in search of a diamond mine. Years went by, and about the time he had spent the last of his money, the man who bought the farm, while plowing one day, turned up a peculiar looking stone which attracted his attention. Upon closer examination it proved to be a diamond, and it soon developed that the farm which had been sold was really a diamond mine all the while. If the original owner had only stayed upon the farm, attending to the duties right at his hand, it would only have been a matter of time before he would have been the possesssr of all he desired.

May we not apply the moral of this legend to the Electrical business in Chicago? I thoroughly believe that the opportunities in this country, and particularly in Chicago, are as good as can be found anywhere, and that if we dig deep enough right where we are, we will attain our full measure of success.

INTERNATIONAL ENGINEERING CONGRESS,

St. Louis, Mo., October 3-8, 1904.

Under the Auspices of the American Society of Civil Engineers.

CIRCULAR No. 2.*

The list of subjects for discussion at the Congress, published February 1st, 1904, has been amended as follows:

Change title of subject No. 32 to read,

32. Mining:
    - *a.* Surveying;
    - *b.* Hoisting;
    - *c.* Ventilation.

Add the following subjects:

34. Gas Engines.
35. Surveying.
36. Ocean Hydrography.
37. Wharves and Piers.

Papers from the standpoint of American Practice have already been assured on the various subjects as follows:

HARBORS, NATURAL WATERWAYS, ARTIFICIAL WATERWAYS AND FORTIFICATIONS:
By Officers of the Corps of Engineers, U. S. A.

LIGHTHOUSES AND OTHER AIDS TO NAVIGATION:
By Officers of the Lighthouse Board, U. S. A.

ORDNANCE:
By Officers of the Ordnance Department, U. S. A.

SURVEYING:
By officers of the U. S. Coast and Geodetic Survey.

NAVAL ARCHITECTURE:
By Rear Admiral W. L. CAPPS, Chief Constructor, U. S. N.

DRY DOCKS:
By Rear Admiral M. T. ENDICOTT, Chief of Bureau of Yards and Docks, U. S. N.

TRAFFIC ON IMPROVED WATERWAYS, etc.:
By EDWARD P. NORTH, New York City.

PURIFICATION OF WATER FOR DOMESTIC USE:
By ALLEN HAZEN, New York City:

PURIFICATION OF WATER FOR THE PRODUCTION OF STEAM:
By J. O. HANDY, Pittsburg, Pa.

TURBINES AND WATER WHEELS:
By Professor GARDNER S. WILLIAMS, Ithaca, N. Y.

IRRIGATION:
By ELWOOD MEAD, Chf. Irrigation Investigations, Washington, D. C.

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*The preliminary announcement (Circular No. 1) was printed in the JOURNAL for February, 1904, vol. ix, page 91.

RAILROAD TERMINALS:
By ELMER L. CORTHELL, New York City.

UNDERGROUND RAILWAYS:
By WILLIAM BARCLAY PARSONS, New York City.

LOCOMOTIVES AND OTHER ROLLING STOCK:
By GEORGE GIBBS, New York City.

LIVE LOADS FOR RAILROAD BRIDGES:
By HENRY W. HODGE, New York City.

THE SUBSTITUTION OF ELECTRICITY FOR STEAM AS A MOTIVE POWER:
By JAMES G. WHITE, New York City.

SEWAGE DISPOSAL:
By GEORGE W. FULLER, New York City.

DISPOSAL OF MUNICIPAL REFUSE:
By RUDOLPH HERING, New York City.

VENTILATION OF TUNNELS:
By CHARLES S. CHURCHILL, Chief Engineer, Norfolk and Western R. R., Roanoke, Va.

HIGHWAYS:
By JAMES OWEN, Newark, N. J., and WILLIAM E. MCCLINTOCK, Boston, Mass.

CONCRETE AND CONCRETE-STEEL:
By EDWIN THACHER, New York City.

DEEP FOUNDATIONS:
By JOHN F. O'ROURKE, New York City.

THE MANUFACTURE OF STEEL:
By WILLIAM METCALF, Pittsburg, Pa.

TESTS OF MATERIALS OF CONSTRUCTION:
By WILLIAM R. WEBSTER, Philadelphia, Pa.

PASSENGER ELEVATORS:
By THOMAS E. BROWN, New York City.

PUMPING MACHINERY:
By IRVING H. REYNOLDS, Youngstown, Ohio.

DREDGES: THEIR CONSTRUCTION AND PERFORMANCE:
By A. W. ROBINSON, Montreal, Canada, and F. B. MALTBY, Memphis, Tenn.

ELECTRICAL POWER—GENERATING STATIONS AND TRANSMISSION:
By L. B. STILLWELL, New York City.

ENGINEERING EDUCATION:
By Professor ROBERT FLETCHER, Hanover, N. H., and Professor CALVIN M. WOODWARD, St. Louis, Mo.

WHARVES AND PIERS:
By JOHN A. BENSEL, New York City.

Advices recently received indicate much interest in the Congress in Europe, and many papers from England, France, Holland and other foreign countries seem to be assured.

CHAS. WARREN HUNT,
Secretary of Committee.

220 WEST 57TH STREET,
NEW YORK, March 12, 1904.

The American Society of Mechanical Engineers.

The spring meeting for this year of the **American Society of Mechanical Engineers** will be held in Chicago May 31st to June 3d, inclusive.

The Institution of Mechanical Engineers (of Great Britain) will also be here in joint session with the A. S. M. E.

The headquarters of the Society will be at the Auditorium, where also the morning sessions of the convention will be held. The evening sessions will be held in the Music Hall, Fine Arts Building, adjacent to the Auditorium. The members of the Foreign Institution will present papers at this Chicago meeting on the Steam Turbine, Gas Engine, Motor Cars, Hydraulic and Electric Cranes, Induction Fans and Garbage Destructors. Papers will probably be presented showing American practice on similar subjects, but also including the power plant of the Tall Office Buildings, Locomotive Testing Plants, Shop Management, Modern Machine Tools, etc.

The local committees are preparing a program and arranging for an interesting series of meetings and trips to points of interest in and around Chicago, as well as sundry social functions.

The local executive committee, composed of the Chairmen of the several local committees having these matters in hand, is as follows:

MR. LOUIS MOHR, 32 Illinois St.	Finance.
MR. G. M. BRILL, 1134 Marquette Building	Entertainment and Excursion.
MR. W. L. ABBOTT, 139 Adams St.	Hotels and Reception.
MR. F. W. LANE, 1660 Monadnock-Block	Printing.
MR. W. H. V. ROSING, 1 Park Row	Transportation.
PROF. P. M. CHAMBERLAIN, Lewis Institute	Meetings.
CAPT. R. W. HUNT, 1121 Rookery	Chairman, Executive Committee.

American Institute of Electrical Engineers.

A convention of the **American Institute of Electrical Engineers,** under the auspices of the Transmission Committee, Ralph D. Mershon, Chairman, will be held in Chicago, June 21st and 22d, 1904, to consider the general subject of High Potential Transmission of Electrical Power. The programme thus far made up will include discussion of the following subjects:

1. Steel vs. Wooden Insulator Pins.
2. Line Construction with Steel Supporting Structures and Long Spans.
3. Bare vs. Insulated Conductors for Inside High Tension Wiring.
4. Lightning Protection for High Tension Lines.
5. Protection of Cables from Arcs Due to Failure of Adjacent Cables.
6. Conditions for Continuous Service Over Lines Operated in Parallel.
7. Report of the Transmission Committee on Data Collected Relative to Transmission Plants.

It is expected that the leading Electrical Engineers in the country interested in these matters will be in attendance.

*The meetings of the convention will be held in the rooms of the Western Society of Engineers, Monadnock Block, Chicago.

JAMES LYMAN,
Chairman Local Committee.

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*The date of the convention being the same as that of the National Republican convention, round trip tickets to Chicago can be secured for one fare, plus 25 cents.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING, March 2, 1904.

A regular meeting of the Society (No. 516) was held in its rooms March 2.

The meeting was called to order at about 8:20 P. M. with President Parkhurst in the chair and about 50 members and guests present.

The Secretary read the minutes of the regular meeting of February 3, and of the extra meeting of February 17.

The Secretary reported, on behalf of the Board of Direction, that the following persons had been elected into membership in the W. S. E. under their respective grades:

Arthur B. Crozier, Chicago, Active.
Fred. L. Hartigan, Chicago, Active.
Harry M. Trippe, Chicago, Active.
George Loughnane, Mason City, Iowa, Active.
Harry H. Ross, Cleveland, Ohio, Junior to Active.
Emmons Collins, Chicago, Active.
Wm. J. Vanderkloot, Chicago, Junior.
M. A. Vanderkloot, Chicago, Associate.
Harry B. Merriam, Dubuque, Iowa, Active.
Edward A. Renwick, Chicago, Active.
Wm. A. Converse, Chicago, Active.
Curtis C. Saner, Chicago, Junior.

Also that the following new applications had been received:

B. F. Affleck, Chicago, Associate.
Henry M. Byllesby, Chicago, Active.
Otto E. Osthoff, Chicago, Active.
Arthur S. Huey, Chicago, Associate.
Arthur M. Morgan, Chicago, Active.
Phillip B. Woodworth, Chicago, Active.
William B. Hale, Chicago, Active.
William E. Reynolds, Chicago, Active.
Samuel A. Rhodes, Chicago, Active.
Myron M. Fowler, Chicago.
Albert Scheible, Chicago.
Albert L. Tucker, Chicago, Active.
Hardy P. Kieffer, Chicago, Associate.
James R. Cravath, Chicago.
Horace G. Dimick, Chicago, Active.
Fred. A. Rogers, Chicago, Active.
James G. Wray, Chicago, Active.
Harold Almert, Chicago, Active.

The Secretary reported, from the Board of Direction, the following petition for an Electrical Section, and the action of the Board on the same:

"*To the Board of Directors, Western Society of Engineers, Chicago:*

"GENTLEMEN—The undersigned active members of the Society respectfully petition for the creation of a section of the Society, to be known as the Electrical Section, the object of which shall be the more complete study of matters pertaining to electrical engineering, with the presentation of papers and the discussion of subjects of interest to us in electrical science. It is our desire to hold meetings of the section for the above purpose generally on the second and fourth Fridays of the months, or as may hereafter be decided upon."

The petition was signed by:

W. L. Abbott,
F. B. Badt,
W. D. Ball,
H. M. Brinckerhoff,
W. G. Carlton,
George A. Damon,
P. Junkersfeld,
George M. Mayer,
Richard McCulloch,
George P. Nichols,
Samuel F. Nichols,
Charles A. Pratt,
Ernest F. Smith,
G. B. Springer.

Mr. Abbott offered the following resolutions:

"WHEREAS, On March 1, 1904, a petition was submitted by fourteen active members of the Society, in good standing, asking for the formation of an Electrical Section, Be it

"*Resolved*, That this Board of Direction authorize the formation of such a section, in accordance with Article VII of the by-laws; and be it further

"*Resolved*, That the said Electrical Section be required to perfect its organization and submit to this Board of Direction within three months from this date, for approval, a copy of the rules and regulations for the conduct of its business"—

Which were adopted.

On behalf of the committee appointed to investigate the placing a Standard of Length in Chicago, the Secretary reported progress.

Mr. Sweeney then presented his paper on "The Use of Pulverized Coal under Steam Boilers." Discussion followed from Messrs. Parkhurst, Stroud, Schaefer, C. E. Sargent, Massa, W. L. Abbott, Neville, Mayer, DeWolfe, C. D. Stephens, and Sweeney. The meeting adjourned about 10:20 P. M.

EXTRA MEETING, March 16, 1904.

An extra meeting of the Society (No. 517) was held in its rooms Wednesday evening, March 16.

The meeting was called to order at 8:20 P. M. with President Parkhurst in the chair and about 40 members and guests present.

Mr. Geo. N. Linday abstracted his paper on "Effect on Trusses and Plate Girders due to Imperfect Roller support," which had been printed and sent out in advance to the members.

Mr. Josiah Gibson read his paper on "Railway Bridge Calculation by End Shear Table." This had also been printed and sent out in advance.

Discussion followed from Messrs. Parkhurst, Garrett Davis, Gibson, Linday, Schaub, and Modjeski. The meeting adjourned about 9:30 P. M.

EXTRA MEETING, March 30, 1904.

An extra meeting (No. 519) was held in the Society rooms March 30, 1904. The meeting was called to order at about 8:20 P. M. with Vice-President Hotchkiss in the chair and about 60 members and guests present. Mr. H. Weiderhold, of Philadelphia, was introduced, who addressed the Society on "Asphalt and its Use in the Industrial Arts." Discussion followed from Messrs. Benezette Williams and Finley.

The entertainment committee offered a light lunch at the close of the meeting, which adjourned about 10:30 P. M. J. H. WARDER, Secretary.

ELECTRICAL SECTION.

FIRST MEETING, March 18, 1904.

The first meeting of the Electrical Section, formed on petition from fourteen members of the Society, and intended for those particularly interested in electrical science, and to be largely built up from the members of the Chicago Electrical Association, who have applied for membership in the Society, was held on Friday evening, March 18, 1904. This is meeting No. 518 of the Western Society of Engineers, and was well attended, there being about 180 present, of the members of the Society and their friends.

President Parkhurst opened the meeting, and was responded to by Mr. W. B. Hale, formerly president of the Chicago Electrical Association, and now chairman of the Electrical Section.

Mr. Hale introduced Mr. Geo. A. Damon, M. W. S. E , who presented his paper on "The Opportunities in the Electrical Business," and which was discussed by Messrs. Woodworth, Freeman, McBerty, McMeen, Perrine, Warner, Tucker, Junkersfeld, Sessions, Miller, Lavers, Schuchardt, Marshall, Mabbs, and Almert. This paper and the discussion is printed elsewhere in this number of the JOURNAL.

Mr. Parkhurst's opening address is as follows:

It is my privilege to welcome you to this, the first meeting of the Electrical Section of the Western Society of Engineers.

As you are aware, this section has been formed largely from the members of the Chicago Electrical Association, who are not strangers to these rooms. They have had headquarters here for some time, and the thought of affiliation has undoubtedly been frequently presented. About three months ago a formal petition was received from the Chicago Electrical Association, addressed to the Board of Direction of the Western Society of Engineers, requesting that such a union might be effected. The matter was discussed by the Board of Direction, and met with great heartiness in favor of a consolidation. The necessary changes in the Constitution and By-laws, to permit the formation of sections of this nature, were made in the usual order of handling such work. The result has been that up to the present some twenty-five or thirty of the members of the Chicago Electrical Association, who were not before this time members of the Western Society of Engineers. have signified their desire to become members of the Electrical Section—partially formed but not fully organized under the provision of the by-laws, which provide that this Section may have its own meetings, its own rules for the conduct of the organization, its own chairman, with other minor officers, and may conduct itself, within reasonable bounds, as an independent section, at the same time being under the direction of the parent society, and being in touch with it in all essential points. If the organization has not yet been entirely perfected, it is a matter of but a small amount of detail to complete it, and the Section should be in perfect working order within a very short time. Our by-laws have provision in this respect, with which I believe you are all familiar, as they have been quoted in the various circulars, and I will not, therefore, discuss them any more in detail.

In behalf of the older members of the Western Society of Engineers, I will say that we believe there is room in our quarters, in our library, and in all our work, for this addition, and that the union of the two societies should give to both an increased strength and power which may be felt in the community.

I have the pleasure of calling upon the Chairman of the Section, Mr. W. B. Hale, who will take charge of the meeting for the remainder of the evening.

Mr. Hale replied as follows:

Members of the Electrical Section of the Western Society of Engineers:

Mr. Parkhurst has so ably set forth the formation of the Electrical Section, its organization, and its relation to the parent society, that there is very little left for me to say. I shall, however, make a few remarks in regard to what we hope to accomplish in the future.

There seems to be an opportunity in Chicago for an electrical organization of a strictly local character; one that will devote its energies and activities largely to local interests. The Chicago branch of the American Institute of Electrical Engineers is discussing very ably, and with great benefit to the whole country, questions of national importance, but not very often questions of local interest. Now that the Chicago Electrical Association has affiliated with the Western Society of Engineers we have a chance to do a great deal more than in the past. We hope to make the Electrical Section the leading electrical society of the middle west, and of great value and usefulness to all electrical engineers. In order to do this we will need assistance, and I would like to say to the visitors present that we need your help, and we hope you will give it by joining the Electrical Section and taking an active part in its proceedings.

The best chairman for an occasion of this kind is one who says the least, and I shall therefore make no further remarks on the subject of the Electrical Section. At the close of the meeting the Secretary will be pleased to furnish any additional information that may be desired.

We have met this evening to consider and discuss "The Opportunities in the Electrical Business," by Mr. George A. Damon. We are all interested in this subject—the manufacturer and the employee, the undergraduate, the young man entering the electrical business, and many others. To these it is a matter of great importance.

And for those of us who are well established in business it is not too late to mend. We might want to adopt a new profession. Mr. Damon, on account of his position as managing engineer of the Arnold Electric Power Station Company, and his connection with different societies, among them being the American Institute of Electrical Engineers and Western Society of Engineers, giving him a wide acquaintance in the electrical field, has been able to obtain some very valuable information, all of which has not been incorporated in his paper.

I have now the pleasure of asking Mr. Damon to present his paper before you this evening.

The meeting was a very interesting one, and did not adjourn until nearly 11 P.M.

J. H. WARDER, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for February, 1904, we have the pleasure to report the following additions to the library and gifts from donors named:

MISCELLANEOUS GIFTS.

Jackson, Geo. W., M. W. S. E., Report on a High Pressure Water System to the Commission on High Pressure Water Systems for the City of Chicago, 1904. Pamphlet.

Rowe, Samuel M., M. W. S. E., "Preservation of Timber," by S. M. Rowe, revised edition, 1904. Morocco.

Seafert, Wm., Associate M. W. S. E., "Architects and Engineers Handbook of Reinforced Concrete Constructions." L. J. Mensch. Pam.

Chanute, O., M. W. S. E., "Aerial Navigation," by O. Chanute. March, 1904. Pam.

Morison, Robert S., Cambridge, Mass., "The New Epoch," by Geo. S. Morison. 1903.

Tratman, E. E. Russell, M. W. S. E., "Drainage of Farm Lands," by C. G. Elliott. Pamphlet.

"A Dual or Light and Heavy Gauge Railway System for India." Pamphlet.

"The Greatest Economic Improvement in Railways." Pam.

De Wolfe, E. C., M. W. S. E., March number, "Electrical Mining," Vol. 1, No. 1, 1904.

Marston, Prof. A., M. W. S. E., Civil Engineering Dept., Iowa State College, "Drainage Engineering in Iowa." Pamphlets.

Hammond, Alonzo J., 2d annual message of Mayor of South Bend, Ind. Jan., 1904.

Fireproof Publishing Co., New York, 2 pamphlets, "Fireproof," January and February, 1904.

Commonwealth of Massachusetts, "Report of Charles River Basin Commission, Oct. 1, 1903."

"Camp and Plant," Denver, Colo., 3 pamphlets, Vol. V., No. 6, Feb. 20, 1904.

Pierce, Richardson & Neiler, Chicago, 16 pamphlets, "Science." 1903.

Peabody Coal Co., Chicago, 1 cloth bound volume, "Economical Burning of Coal without Smoke, with especial reference to the use of Washed Coal," by A. Bement.

John Crerar Library, Chicago, "List of Books on Industrial Arts." Oct., 1903. Pam.

Commissioner of Water Works, Cincinnati, Annual Report, Board of Trustees, 1903.

Brookline, Mass., Water Board, Report for 1903.

Colby, Albert Ladd, "Non-corrosive Nickel Steel Boiler Tubes," Nov. 19, 1903.

City of Chicago, Law Department, "Report of J. F. Smulski, City Attorney," Dec. 31, 1903.

Greely, S. S., "The Public Lands Exception," March, 1904.

American School of Correspondence, Armour Institute of Technology, Bulletin No. 2, 1904.

Connecticut Bureau of Labor Statistics, 8 vols., cloth—4th, 6th, 11th, 12th, 13th, 15th, 18th and 19th annual reports—1888-1903.

Civil Engineers' Club of Cleveland, List of Officers and Members, 1904.

Purdue University, Bulletin No. 4, Annual Catalogue, 1903-4. Pam.

Chicago Historical Society, Cataloge 1903-4.

DePauw University, Greencastle, Ind. "Addresses delivered on Inauguration Day, December, 1903." Pam.

New Jersey Sanitary Association, Proceedings, 29th annual meeting, 1903.

John Wiley & Sons, New York, Alternating Currents, their Generation, Distribution and Utilization, by Hanchett. 1904. Cloth.

Massachusetts Railroad Commissioners, 35th annual report. 1904.

Dept. of Commerce and Labor, Bureau of the Census—Bulletin No. 7, Estimates of Population of the larger Cities of the United States, 1901-1902-1903.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey, Dept. of Interior, Washington, D. C.
Production of Iron Ores in 1902. Birkinbine. Pamphlet.
" " Coal in 1902. E. W. Parker. "
" " Natural Gas in 1902. Pamphlet.
" " Petroleum in 1902. Oliphant. Pamphlet.
" " Gold and Silver in 1902. Roberts. Pamphlet.
" " Mica in 1902. Holmes. Pamphlet.
" " Manganese Ores in 1902. Birkinbine. Pam.
The Stone Industry in 1902. Pamphlet.
Bulletin No. 208, Nevada, South of the Fortieth Parallel, and adjacent positions of California. Spurr. 1903. Pamphlet.
Bulletin No. 218, The Coal Resources of the Yukon, Alaska. Collier. 1903. Pamphlet.
Bulletin No. 219, Ore Deposits of Tonopah, Nevada. Spurr. 1903. Pamphlet.
Bulletin No. 220, Mineral Analyses from Laboratories of the U. S. Geol. Survey, 1880 to 1903. Clarke. Pamphlet.
Bulletin No. 221, Biography and Index of North America, Geol. Paleontology, Petrology, Mineralogy. 1902. Weeks. Pam.
Bulletin No. 222, Publications of Hayden, King, Powell & Wheeler Survey, by Schmeckebier. 1904.
Catalogue and Index. Pamphlet.
Monographs, Vol. XLVI, Menominee Iron Bearing District of Michigan. By Bayley. 1904. Cloth bound.
24th Annual Report of the Director of the U. S. Geol. Survey to the Secretary of the Interior. 1902-1903. Cloth bound.
U. S. Coast and Geodetic Survey, Washington, Report of Superintendent, showing Progress of Work. July 1, 1902 to June 30, 1903. Cloth bound.

EXCHANGES.

American Electrochemical Society, Philadelphia. Officers and Directory of Members, February, 1904. Pamphlet.
Western Railway Club, James J. Taylor, Secretary, 2 vols., cloth—Proceedings of Club, 1901-1903.
University of Montana, M. J. Elrod, 3 pamphlets.
"Summer Birds of Flathead Lake, Additional Notes."
"President's Report, 1902-1903."
Association of Railway Supts. of Bridges and Buildings, Proceedings, 13th annual convention, October, 1903. Pam.
American Institute of Mining Engineers, Transactions for 1902, Vol. 33.
University of Texas Mineral Survey, Bulletin No. 7, "Report of the Progress for the year 1903."
New Hampshire College Agricultural Experiment Station, Bulletins 105, 106 and 107, January and February, 1904. 3 pamphlets.
Iowa Engineering Society, Proceedings 15th annual meeting, Jan., 1903.
Engineers' Society of Western New York, Membership List, March, 1904.
Institution of Engineers and Shipbuilders in Scotland.
List of Members and Students, 1903-4.
11 vols., cloth bound, Proceedings 1893-1903, Vols. 36-46.
American Ry. Engineering & Maintenance of Way Association, Bulletin No. 49.

TRADE CATALOGUES.

The Trump Mfg. Co., Springfield, O., "High Grade Turbines." Pamphlet.
E. H. Stroud & Co., Chicago, "Cyclone Powdered Coal Burning System."
American Track Supply Co., Chicago, "Track Economy," 1904.
The Roebling Construction Co., Chicago, "The Baltimore Fire, and the Iroquois Theatre Fire."
Eugene Dietzgen & Co., Chicago, Catalogue 1904-5, Drawing Materials and Surveying Instruments.

BOOK NOTES.

The Design of Steel Mill Buildings, and the Calculation of Stresses in Framed Structures, by Milo S. Ketchum, C. E., Assistant Professor of Civil Engineering, University of Illinois. Engineering News, New York. 1903. Cloth, 6 x 9 in., pp. 567. $4.00.

In bringing out this volume the author has shown his need in the class room of a practical treatise on the designing of steel structures, and his desire to put his students in touch with the broader practice of design, rather than to confine them to theory and the solution of theoretical problems.

It is a sign of real progress when our universities call to their teaching forces, men who have gone out into the practical field and who have been brought in contact with problems of design and construction from a commercial standpoint, and are thus able to fully appreciate the position of the young engineer at the beginning of his career, handicapped with a surfeit of theory, but with no adequate knowledge as to the best means of applying it.

The work being primarily intended as a text book, is divided as to topics in the logical manner in which the student of the subject is expected to develop; Part I dealing with loads, Part II with stresses, and Part III with design of structures to resist them.

In Part I the author gives a new empirical formula for approximating the dead load of roof trusses, deduced from actual shipping weights of mill building trusses.

The various kinds of loads are fully treated in separate chapters.

In Part II are given both analytical and graphical methods of determining moments, in such a manner that one is at once impressed with the author's preferernce for the latter method.

His graphic solution of the transverse bent is a distinct addition to engineering knowledge, and deserves the careful attention of every designer of frame structures for its concise treatment of a complicated problem.

Another much neglected subject, that of eccentric riveted connections, is treated in a chapter on combined and eccentric stresses, but is not given the attention which it really deserves.

It is in Part III that the author's best work is found, and a perusal of this part would be to the advantage of any engineer.

No pains have been spared in collecting the best examples of the several familiar types of framing, with their details, and other types are presented which are new or at least not in general use.

The saw tooth or weaving shed roof is not as fully treated as its value warrants, and especially the very excellent modified form which he presents should be worked out more in detail, for while not giving so large a proportion of glass area to surface covered, it admits of better gutters and the use of monitor sash windows, the lack of which has been such a drawback to the entirely closed design.

Several chapters are devoted to the minor but none the less important details of construction, all of which show careful study and a knowledge of the necessities involved.

The subjects of shop costs and shop details are fully treated, and great stress is laid on the relation and effect of the latter on the former.

In Part IV are given descriptions of several notable examples of framed structures with illustrations, stress and section diagrams and details, while in an Appendix are given general specifications for steel mill buildings, which are very complete and concise.

F. L. H.

Alternating Currents—Their Generation, Distribution and Utilization. By George T. Hanchett, M. E. John Wiley & Sons, New York. 1904. Cloth, 5 x 8 in.; pp. 175; figures in the text. $1.00.

This is a book that will be, as the Preface states, of special interest to practical engineers in charge of lighting and power plants and construction work who have a thorough knowledge of direct current work, but who understand comparatively little of alternating current phenomena. It will also be of use to beginners in the study of the subject named above.

The author has written the work in a good, common sense, entertaining manner that is easily digestible for any one interested in the subject. The work is made con spicuous by a lack of mathematical equations, which are almost invariably strewn so liberally throughout most of the treatises on this subject and which make it so difficult for those not versed in higher mathematics. There are not more than two dozen formulæ throughout the book, and these do not involve a knowledge of more than elementary trigonometry and algebra.

The first chapter ingeniously treats of the well known, but somewhat dangerous subject of "Hydraulic Analogies," which give the reader a fair comprehension of the phenomena of inductance, capacity and the results obtained by introducing them into alternating current circuits.

In the second chapter the author treats of relation between direct current and alternating current, and shows the graphic composition of pressure, current and power waves with lagging and leading power factors. This is, perhaps, the most valuable chapter in the book.

With the exception of several good chapters on the theory of polyphase currents with vector analysis of the same and copper calculations, the rest of the book is devoted to the theory and application of standard lighting and power apparatus.

The book is well gotten up, is very carefully written and contains many first-class and up to date illustrations and diagrams. S. G.

Compendium of Drawing. PART I—Compiled from the Instruction Papers in the Architectural Course of the American School of Correspondence at Armour Institute of Technology, Chicago, Illinois; pp. 410. PART II—Compiled from Instruction Papers in the Mechanical Engineering and Sheet Metal Pattern Drafting Courses, at "Armours;" pp. 507. Cloth, large 8vo; fully illustrated; price $5 00.

These two volumes consist of twelve of the eighty-nine regular instruction papers as sent out to the students. The primary object of the volumes is to call attention to character of the courses offered and arouse prospective students with a desire for further information along the same lines. The papers are so well chosen and presented in such a clear and practical manner as to make them valuable to students and draftsmen generally. The illustrations and drawings are numerous and very good

Part I begins with a description of the drafting instruments and their uses, followed by elementary geometrical problems. More difficult problems in Projections and Shades and Shadows follow. The problems are very clearly explained by means of well executed drawings. Perspective and architectural lettering are also treated.

The subjects treated in Part I are as follows:

Mechanical Drawing, by Ervin Kenison, S. B., Instructor in Mechanical Drawing, Massachusetts Institute of Technology.

Shades and Shadows, by Harry W. Gardner, S. B , Asst. Prof. of Architecture, Massachusetts Institute of Technology.

Perspective Drawing, by William H. Lawrence, S. B., Assoc. Prof. of Architecture, Massachusetts Institute of Technology.

Pen and Ink Rendering, by D A Gregg. Lecturer in Pen and Ink Drawing, Massachusetts Institute of Technology.

Architectural Lettering by Frank C. Brown, of Boston.

The papers of Part II are:

Working Drawings, by Charles L. Griffin, S. B. Mech. Engr.—The Semet-Solvay Co.

Mechanism, by Walter H. James, S B., Instructor in Mechanical Engineering, Massachusetts Institute of Technology.

Machine Design, by Charles L. Griffin, S. B , Mech Engr. Semet-Solvay Co.

Sheet Metal Pattern Drafting and Tin-smithing, by Wm. Neubecker, Instructor, Sheet Metal Department, New York Trade School.

Part I contains many practical problems treated in an elementary manner. The theory is clearly expressed in the text and illustrated by excellent sketches and drawings.

In Part II a similar method of treatment has been followed with illustrated examples for practice, following the definitions and exposition of methods. Formulas and useful tables are also included.

To those in need of such instruction, these books can be recommended.

H. C. L.

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each applicaton, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

JOHN F. WALLACE, M. W. S. E.
CHIEF ENGINEER OF THE PANAMA CANAL.

Journal of the
Western Society of Engineers.

VOL. IX. JUNE, 1904. NO. 3.

FLEXURE OF REINFORCED CONCRETE BEAMS.*

By Prof. W. K. Hatt, Purdue University, Lafayette, Ind.

Presented April 6, 1904.

The writer here presents the following:

(1) A short account of his experiments.
(2) A simple formula.
(3) Equations of flexure (see appendix.)
(4) Diagrams representing equations.

The writer has been conducting experiments in which he has been assisted by students in the School of Civil Engineering, to determine the proper method of analysis of the strength of a combination of steel and concrete under flexure. He has been concerned chiefly with experiments which would serve to test the validity of this analysis. For this purpose it was necessary to use uniform materials of a high quality. The experiments were therefore conducted on beams made of rich concrete and reinforced with plain bars without any bond other than natural adhesion between the cement and the steel. In the construction of the beams the proportion of the steel was so modified and so placed in various portions of the cross-section as to create a variety of conditions in order that the flexibility of the theory might thus be tested. The concrete represented good arch-ring concrete. No attempt was made to develop those weaknesses which at times result in particular kinds of failure in certain forms of practical construction. Accompanying the writer's tests on beams have been tests on steel and on concrete both in tension and compression.

It is no part of the writer's present purpose to reproduce the algebraic work back of the equations which are the result of his analysis. The original paper containing this analysis may be found in the Transactions of the American Society for Testing Materials, Vol 11, page 161, and in the Engineering News, July 17, 1902. The equations are here reproduced in an Appendix. Figures 1, 2 and 7 of the present paper are take from the references cited. The theory takes account of that part of the bending moment due to tensional forces in the concrete; and it supposes a parabolic law of variation of the stress in the concrete of the beam with the distance from the neutral axis.

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*Note by Author: This paper was presented before the Society after practically the same matter was embodied in a discussion by the author of Bulletin No. 50 of the American Railway Engineering and Maintenance of Way Association.

The tests were on beams 8 x 8 inches in cross-section made of 1-2-4 concrete. The stone was limestone, crusher run below one inch. The proportions were by loose volume. The beams were tested under a center load on an 80-inch span. The tests have disclosed the following facts:

(1) The flexibility of reinforced concrete beams, that is, the degree of deflection before cracks, visible to the naked eye, are formed in the lower part of the beam, is about ten times that of a beam without reinforcement. This observation checks Considere's results, who found that reinforced concrete would, without cracking, submit to an extension at least ten times that ordinarily experienced by plain concrete. The benefit of this increased flexibility is that thereby the strength of the steel in tension and the strength of the concrete in compression may be largely utilized. The strength of a beam reinforced with steel rods whose cross-section constituted 2 per cent of the cross-section of the beam was from four to five times that of a plain concrete beam. In fact beams may be designed in which factors of safety in all the three elements, that is, steel in tension, concrete in compression and tension may be very nearly equal. Steel of an especially high elastic limit is needed, however, to devolop the compressive strength of 1-2-4 concrete.

(2) In the presence of this .1-2-4 concrete the first visible failure was a tension crack in the concrete near the center of the beam. The failure was not due to a slipping of these plain bars in the surrounding concrete nor to the effects of shear. Beams tested on a 40-inch span yielded similar tension cracks. In certain further tests, however, made on leaner concretes, 1-3-6, failure has been due to a pulling out of the bar from the concrete near the end of the beam. Accompanying this pulling out, was a crack in the beam running up from the support towards the load. This latter crack is sometimes called a shear crack, but is really due to tensional stresses which are the resultant of internal shears and longitudinal stress. The value of some mechanical bond or of some form of stirrup or abutment in such cases will be evident. The only failure purely of the nature of a shear is the separation which sometimes occurs in a horizontal plane just above the reinforcement. This latter separation has only occurred in the writer's experience in a beam which was so highly over-reinforced that there was very little concrete between the steel bars.

It may be noted the writer's tests were under conditions of concentrated loading, and that failure near the end of a beam, due to shear, would be more likely under uniform loading; since for the same center moment the shear is double under a condition of uniform load as compared to concentrated loading. The value of the vertical shear per square inch of cross-section of the beam tested by the writer was on the maximum about 160 pounds per square inch. The resultant of two shears at right angles to each other is a tension of the same amount and this might easily rupture ordinary concrete. The tensile strength of the concrete in the 1-2-4 beams was nearly 300 pounds per square inch. The adhesion and friction between the steel and concrete was about 700 lbs. per sq. in. of surface.

After the first visible crack is formed in tension it spreads upwards. Then the strength of the steel in tension and the concrete in compression is brought into play. The higher the elastic limit of the steel the more one postpones the point of rapid increase of the width of this crack, and when steel is used of sufficiently high elastic limit, and in sufficient quantity, the compressive strength of the concrete in the upper flange will be developed. In the writer's tests of stone concrete beams reinforced with wrought iron whose elastic limit was 36,000 pounds per square inch, a 2 per cent reinforcement failed to develop the compressive strength of the concrete.

Fig. 6 shows a view of the cracked beams.

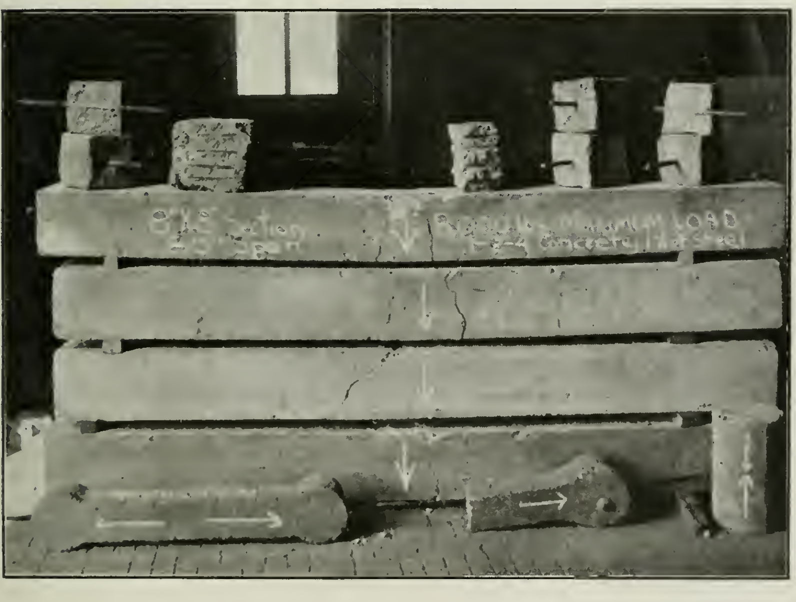


Fig. 6.

In no tests with 1-2-4 concrete beams or 1-5 gravel concrete beams reinforced with less than 2 per cent of metal of a low elastic limit has the first visible failure been other than a crack in tension at the center of the beam. The above remarks also apply to tests of 1-5 gravel concrete beams of similar size and loading.

(3) The behavior of the reinforced concrete beams under flexure was as shown in Fig. 1 below. It will be noticed that the ratio between load and deflection remains very nearly constant up to point A, which is one-half to one-third the maximum strength. The diagram then becomes of less inclination to the deflection axis and the deflection proceeds until a crack visible to the naked eye appears in the tension side of the beam and a deflection of about one five-hundreth part of the span. In the case of gravel concrete beams the maximum load coincides with the load at first crack and the diagram beyond the point A has a decided curvature.

It is probable that at point A there are minute cracks invisible to the naked eye, and the writer understands that certain observers have recently developed these minute cracks. These are explained by the following considerations: When a piece of plain concrete is pulled in tension the first minute crack which forms is afterwards rapidly developed into a plane of rupture; but when the same concrete bar is reinforced with steel rods the spreading of this minute crack is prevented with the consequence that the concrete bar cracks in a number of places throughout the entire length, and that the extension at the time of failure is much greater than that extension experienced by a plain bar at the time of failure. Thus, Considere has found, and his tests have been checked by the writer, that plain concrete in tension experiences an extension at the time of rupture of only one-tenth that experienced by reinforced concrete. In other words the steel acts as hair does in plaster.

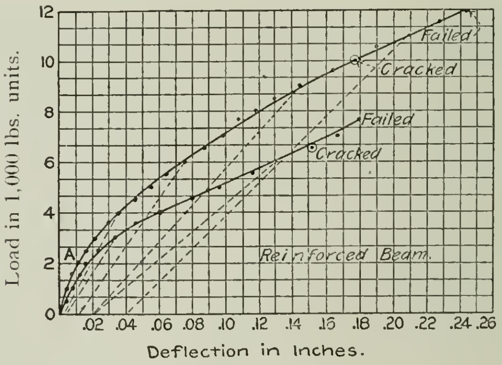


Fig. 1.

A diagram representing a test of reinforced concrete in tension is shown below, Fig. 2.

In the case of a reinforced concrete bar under tension we may suppose that these minute cracks begin to form at a point, P, preceding the rapid increase in elongation in Fig. 2, but no one of these minute cracks spreads to form a visible crack until the further extension of the bar.

It does not seem that these minute cracks are of any practical consequence. The crack which is called by the writer "first crack" is a crack visible to the naked eye such as would be an evidence of weakness in an actual structure.

(4) Results of tests indicate that reinforcement in the compression flange adds but little to the resisting moment.

The writer has advanced a theory to account for these three points, A, first crack, and maximum strength, and finds the theory is flexible enough to predict the behavior of a beam at various stages of the test when such beam is reinforced with different percentages of metal placed at different parts of the cross-section. The equations of the theory are complicated and difficult of computation, but that part of the expression for bending moment in brackets in equation 5, page 238, may be represented graphically or may be replaced with a simple formula which may be called the "Straight Line Formula for Reinforced Concrete Beams." While these equations are complicated they approach so nearly a straight line that for ordinary degrees of reinforcement the latter will serve all purposes. The writer proceeds to give this Straight Line Formula to cover the test so far made, and he also presents a diagram which shows the nature of the equations in more elaborate theory.

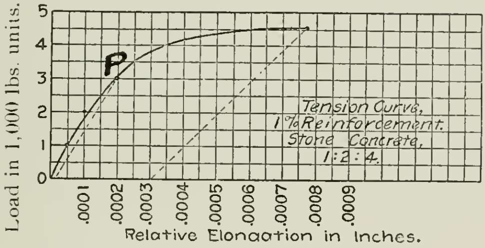


Fig. 2.

STRAIGHT LINE FORMULA.

$M = Ktbh^2$.

Where M = Moment in inch-pounds.

P = Percentage of steel in cross section in lower flange (not to exceed 3).

b = breadth of beam in inches.

h = depth of beam in inches.

t = tensile strength of concrete in pounds per sq. in.
u = the fractional depth of the steel from the top of the beam.
K = a constant which is as follows:
For 1-2-4 stone-concrete beams:
$K = [1/3 + (\frac{7}{4}u - 1)P]$
Or $M = [1/3 + (\frac{7}{4}u - 1)P]tbh^2$
For 1-5 gravel concrete when $u = 7/8$
$M = (1/3 + \frac{3}{4}P)tbh^2$

The value of t may be taken as one-tenth the crushing strength in the case of stone-concrete, and one-ninth the crushing strength in the case of gravel-concrete. This fact has been determined by actual tests made by the writer. The following values have been derived by his tests: See Table I.

The use of this formula must be followed by a computation of the stresses in concrete in compression and steel in tension, otherwise a per cent of steel may be taken which would call for too high values of the strength of the concrete in compression. The computation is best performed by the aid of diagrams mentioned below.

The question as to the proper point at which factors of safety should be fixed is of practical consequence. Either the point of appearance of the first visible crack or the ultimate load may be taken. In certain designs, however, this ultimate load corresponds to a state of failure which is very far advanced and very much beyond the point of the first visible crack. When the beam has a decided set, due generally to the Elastic Limit of the steel being exceeded, the load preceding the set forms a basis of reference for "factor of safety."

ILLUSTRATION OF THE USE OF THE FORMULA.

Find the strength of a beam 8 x 8 inches in cross-section reinforced with 2 per cent of steel, made of 1-2-4 stone-concrete 28 days old. The center of the steel is 1 inch above the bottom of the beam. Assume t = 280 pounds.

$u = 7/8$
$M = bh^2\ 280\ (.333 + 0.55P)$
If $p = 2$ per cent
$M = bh^2\ 401$
If a beam is 8″ × 8″ in cross section
$M = 205312$ inch pounds.
If the span of the beam is 80 inches, the center load = P = 10,260 pounds.
A beam tested under these conditions gave 10,250 pounds load.
The safe load would be about 3,400 pounds.

For use in rough calculations it may be well to state the following rule:

The resisting moment of beams one month old may be put,

$M = K' bh^2$

With units, inches and pounds. The value of K' at the age of one month is as follows:

Concrete of 1-2-4 crusher run, below one inch:

Per Cent of Steel	K′
0	90
1	250
2	400
1-5 gravel:	
1	280
2	480

That is to say, the resisting moment of a reinforced concrete beam with one per cent of steel is 250 times the width times the square of the height. The beams would show a visible crack on the application of this bending moment when soft steel is used.

USE OF A DIAGRAM.

The writer assisted by Mr. C. H. Hall, Purdue, 1903, has plotted in Figs. 3 and 4 two diagrams.

Figs. 3 and 4 enable the strength of beams to be computed when made of different kinds of concrete reinforced with different percentages of steel. They enable a simple formula to be used of the following nature:

$M = Ktbh^2$

Where M = Bending Moment in inch pounds.

b = width of beam in inches.

h = depth of beam in inches.

t = tensional strength of the concrete.

K is a constant which depends on per cent of reinforcement and kind of concrete.

Fig. 3 enables the bending moment to be computed at point A. Fig. 4 enables this bending moment to be computed at the point of first visible crack. The writer desires to say that the lines on these diagrams are simple expressions of equations in Appendix 1, resulting from the application of the theoretical analysis, and they are not to be used with any practical operations until the experimental points have been located on the diagram to establish the application of these lines to practical conditions.

As has been said, the writer has been working to establish the experimental points on these diagrams. Up to the present time his experiments cover the field represented by the lower lines in the diagram. He has shown so far that the theory is elastic enough to predict the strength of beams made with different per-

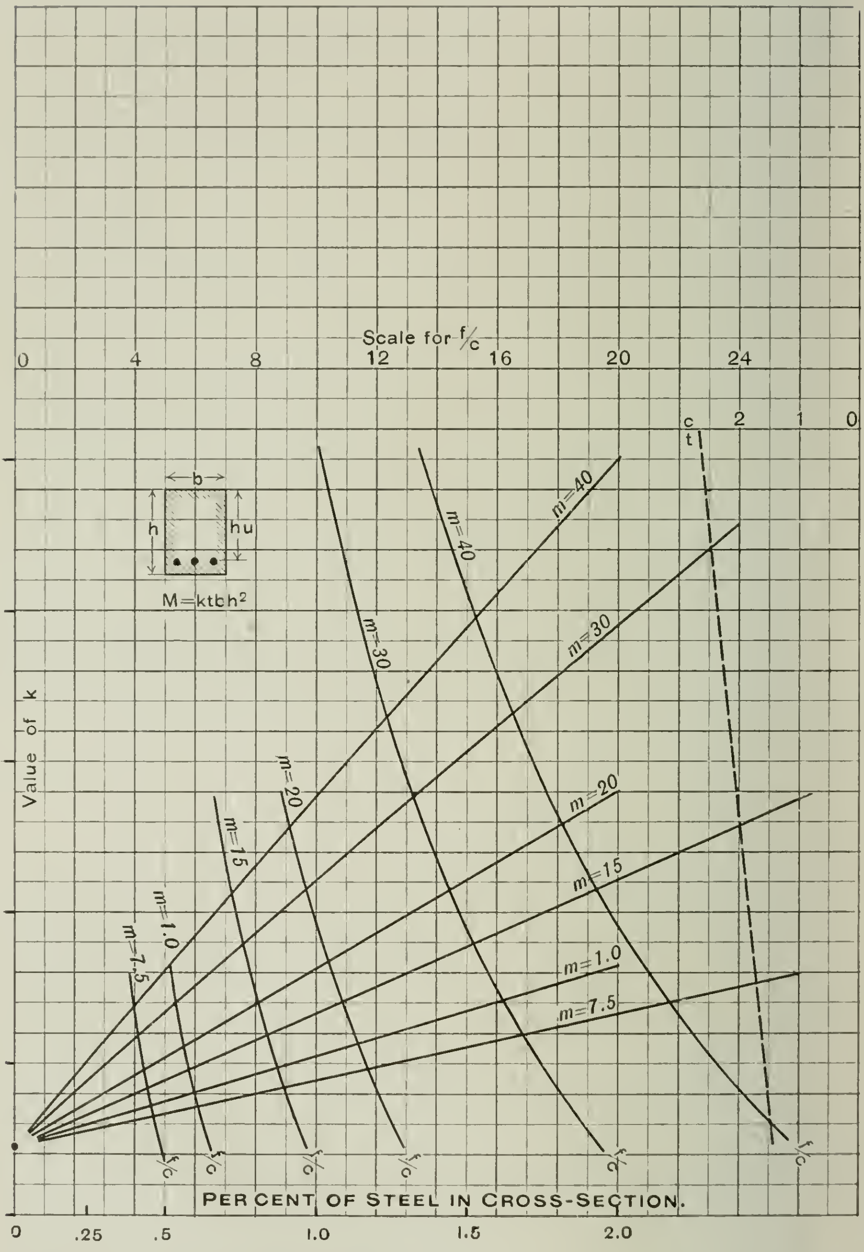


FIG. 3. Diagram showing variation of K, with per cent of steel in cross section: n=2, u=0 95 for point "A."

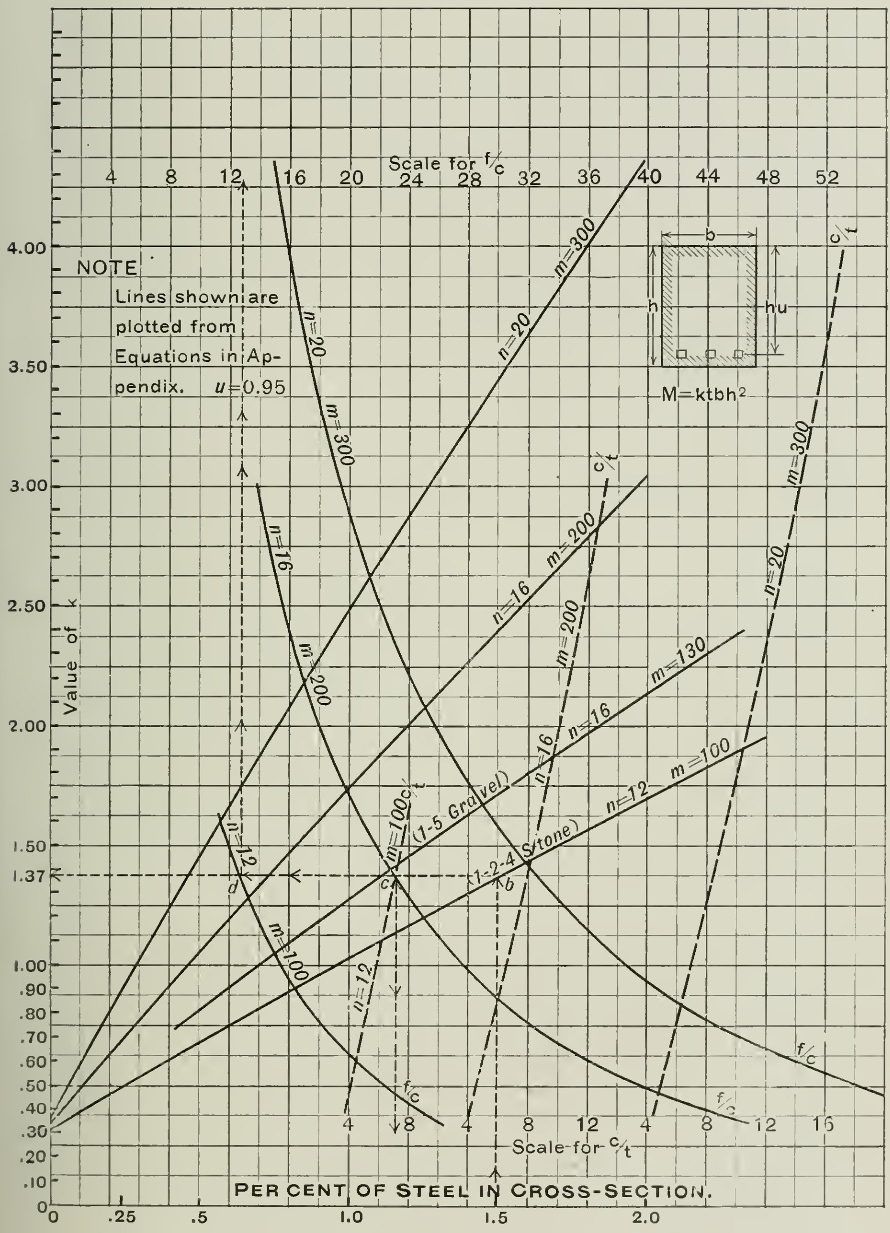


FIG. 4. Diagram showing variation of K, with per cent of steel for point of first crack.

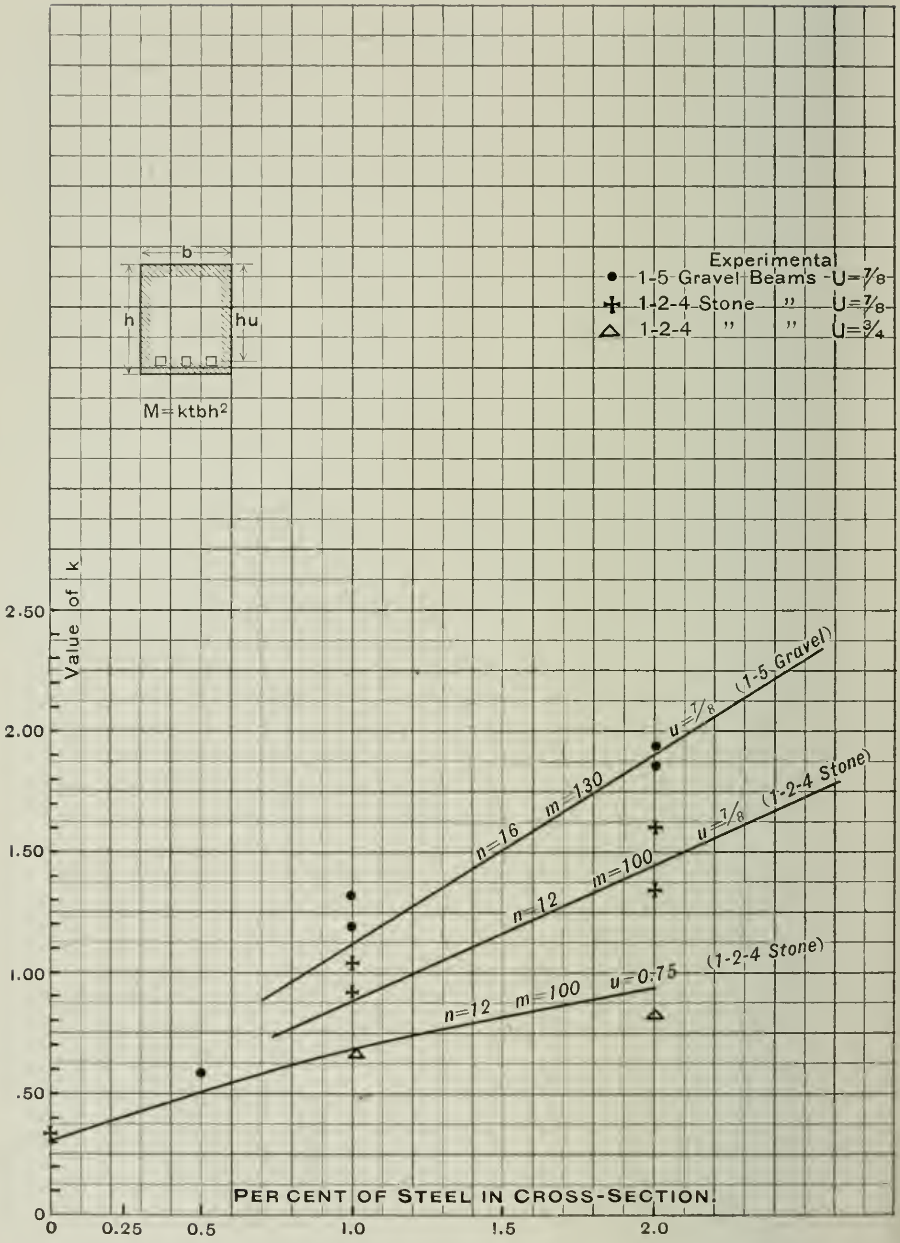


FIG. 5. Diagram showing comparison of theory with experiment. Lines represent equations in appendix.

centages of steel placed at different portions of the cross-section, both for point A and for the point of first visible crack. The results of the experiments are compared to the theory in Fig. 5, by reference to plotted points whose values are gotten from Table II. In the future he expects to conduct experiments to cover the upper lines in the diagram; that is to say, to conduct experiments with lean concrete in which shear will probably be a determinative factor.

The comparison of theoretical and experimental results at point A is not satisfactory.

These diagrams suppose failure to be by bending and not by the effects of shear. The same problem comes up in the design of wooden beams. Before designing a wooden beam one must be sure that equations should be applied for bending and not equations for horizontal shear. With these preliminary remarks the nature of the diagrams are explained as follows:

With the use of the diagram, required the solution of the following problem:

What depth of beam is necessary to carry 10,000 pounds center load on a 10-foot span?

Conditions.—1-2-4 concrete one month old. Compressive strength 2,400 pounds per square inch. Tensile strength 240 pounds per square inch. Reinforcement 1 ½ per cent. Assume depth of reinforcement from top of the beam equal 0.95h.

Referring to Fig. 4, run up from the precentages of 1.5 from the horizontal axis to point b on the line marked n = 12, m = 100, thence horizontally to the axis of K to a value of 1.37.

Then $\frac{M}{bh^2} = 240 \times 1.37$. And the required $M = \frac{10,000 \times 120}{4} = 300,000$

$\frac{300,000}{bh^2} = 240 \times 1.37$

If $b = \frac{h}{2}$ $h = 12.20$

The required beam will then be 6 x 12.2 inches and will require three $\frac{11}{16}$-inch round bars.

To determine what stresses exist in the steel and in the concrete, consult Fig. 4. From point b go horizontally to the left to point c on the line expressing the ratio of $\frac{c}{t}$ and thence down to a value of 7.2 on axis of $\frac{c}{t}$.

Since $t = 240$

Therefore $c = 7.2 \times 240 = 1728$ lbs. per sq. in., stress of the concrete in compression.

From the same point b move horizontally to the left to point d on the line which expresses the ratio of $\frac{f}{c}$, thence vertically upward to the scale for $\frac{f}{c}$ to a value marked 13.

Since $c = 1728$, therefore $f = 1728 \times 13 = 22{,}464$ pounds per square inch, tensile stress on the steel.

The letters n and m on these diagrams refer to constants in the equations given in the appendix.

The present evidence from the writer's experiments point to the fact that constants $n = 12$, and $m = 100$, are suitable for 1-2-4 stone concrete; and $n = 16$, $m = 130$ for 1-5 gravel concrete.

On Fig. 5 have been represented the results of experiments made by the writer. That is to say, the value of K has been computed from the results of experiments using the value of t as ascertained by parallel experiments conducted on concrete of which the beams were made. It will be observed that the tests on 1-2-4 concrete beams shown by the small crosses and triangles, fit the constant $n = 12$, $m = 100$ and $t = 300$ pounds per square inch with a satisfactory agreement. It can be noticed that the theory responds to a change of the value of u from ⅞ to ¾ when tested by the results of these experiments. The lines shown in Fig. 4 also run out to an experimental point corresponding to a plain beam without any reinforcement. The other points of the diagram are for gravel beams which show a greater strength than do stone concrete beams.

The above remarks refer to the comparisons between the theoretical lines and the experimental points on the diagram showing relations at the time of first crack. The agreement is less satisfactory in the case of point A.

TABLE I.

KIND OF CONCRETE				Age	Compression Modulus	Tension Modulus	ULTIMATE STRENGTH	
Cement	Sand	Broken Stone	Gravel				Comp.	Tension
1	2	5	......	90 da.	4,610,000	5,460,000	2413	359
1	2	5	......	28 "	3,350,000	3,800,000	2290	237
1	...	.....	5	90 "	4,800,000	4,510,000	2804	290
1	....		5	28 "	4,130,000	4,320,000	2400	253

The writer desires to quote certain results recently obtained in experiments performed in the Laboratory for Testing Materials in Purdue University.

Table 1 gives the modulus of elasticity and strength of both broken stone and gravel concrete at 28 days and 90 days. The limestone was the product of the crusher below 1 inch. The gravel was excellent pit gravel, including sand and pebbles. The concrete was medium wet. The values quoted are based upon -tests of 37 compression specimens, involving 202 determinations of the modulus in compression and on tests of 27 tension specimens, involving 79 determinations of the tension modulus. From these results it appears that the ratio of the modulus of elasticity of concrete in compression to that in tension is nearly unity.

The ratio of the modulus of elasticity of the steel in tension to the concrete in compression is as follows:

Stone-Concrete	28 days	8.8
Stone-Concrete	90 days	6.6
Average		7.7
Gravel-Concrete	28 days	8.0
Gravel-Concrete	90 days	6.2
Average		7.1

The value of E is obtained not from a tangent to stress-strain diagram but by substracting the set preceding the load at which E is measured. This E is very little affected by the stress at which it is measured.

TABLE II.

COMPARISON OF THEORY AND EXPERIMENT.

Concrete Beams 8in. x 8in.—Center Load on 80in. span.

Theoretical value of K computed from equations in Appendix, using values for first crack:

For 1-2-4 Stone n=12; m=100.
For 1-5 Gravel n=16; m=130.

1-2-4 STONE CONCRETE.

u	Per Cent of Steel	Age, Days	Tensile Strength	LOAD IN LBS.		VALUE OF K			
						EXPERIMENT		THEORY	
				Point A	1st Crack	A	Crack	A	Crack
	0	28	300	1450	2550	0.189	0 336	...	0.332
7/8	1	28	300	2750	7050	0.357	0.920	.	0.920
	2	28	300	3250	10250	0.425	1.340	. . .	1.420
3/4	1	28	300	2500	5000	0.326	0.685	...	0.670
	2	28	. ...	2500	6100	0.326	0.825	...	0.950

A second series of 1-2-4 beams with u = 7/8 were tested in 1904. They were made of weaker concrete than first series in table.

7/8	1	90	300	..	7875	..	1.053	. ..	0.920
	2	90	300	. .	12000	...	1.553	....	1.420

GRAVEL 1-5.

	1/2	90	290	2500	4375	0.336	0.589	...	0.72
7/8	1	90	290	3000	8500	0.404	1.34	....	1.12
	2	90	290	3250	13750	0.437	1.85	....	1.90
7/8	1	28	253	2750	7750	0.425	1.20	..	1.12
	2	28	....	3000	12550	0.464	1.94	....	1.90

NOTE.—The value of n and m used above may be arrived at as follows: *1-2-4 Stone Concrete:* t = 300 lbs. per sq. in. at point at first crack, elongation is one part in 1000 Es = 30,000,000 Ec = 3,600,000 Then $m = \frac{30,000,000}{300 \div \frac{1}{1000}} = 100$

$$n = \frac{3,600,000}{300 \div \frac{1}{1000}} = 12$$

1-5 Gravel: t = 250 The Gravel Beams had the same deflection at point of first crack as the stone concrete beams. $m = \frac{30,000,000}{250 \div \frac{1}{1000}} = 120$

$$n = \frac{4,130,000}{250 \div \frac{1}{1000}} = 16$$

m = 130 was used in Table II to bring closer agreement.

APPENDIX.

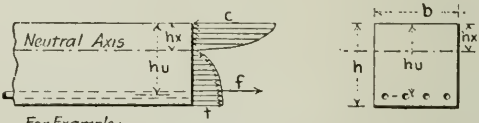
THE EQUATIONS OF FLEXURE OF REINFORCED CONCRETE BEAMS.

The theory, the main analysis of which is indicated below, intends to account for three characteristic points of the load-deflection curve shown in Fig. 1, viz, the point A, the load at first crack, and the load at failure.

The assumptions upon which the theory is based are mainly as follows: (1) The cross-sections of the beam remain plane surfaces; (2) the applied forces are perpendicular to the neutral surface of the beam; (3) the values of the moduli of elasticity obtained in simple tensile and compressive tests will apply to the material when under stress in the beams. (4) There is no slipping between the concrete and the steel reinforcement; and (5) there are no initial stresses in the beam due to shrinkage or contraction of the concrete while setting. The analysis supposes fracture to be due to bending and not to horizontal shear.

If the cross-sections are assumed to remain plane surfaces during flexure, the distortion of any fibre will be proportional to its distance from the neutral axis. It follows that the law of variation of stress will be represented by the stress-strain diagrams for simple stresses.

Following the method of M. Considére in general by applying these diagrams to the cross-section of a beam, we will have the representation of the stresses at different points of the cross-section. These stresses in the concrete and that in the steel reinforcement are shown in Fig. 7.



For Example:
$h = 8''; \; b = 8''; \; hx = \frac{1}{3}h; \; c = 1500$ lbs.; $t = 300$ lbs.;
$f = 20{,}000$ lbs.; $hu = 7''$

FIG. 7. Diagram Indicating Nature of Stresses in Reinforced Concrete Beam.

For the sake of simplicity in the analysis, these stress-strain diagrams are assumed to be parabolic arcs, an assumption which is justified in the case of compressive stress-strain diagrams by an examination of a large number of tests recorded in "Report of

Tests of Metals for the year 1899." Referring to this figure, let

l = length of span; b = width of cross-section.

hx = the distance from the compression face to the neutral axis;

hu = the distance from the compression face to the centre of gravity of the reinforcement;

p = the ratio of the area of steel to that of the cross-section of the beam;

E_s, E_c, E_t = the moduli of elasticity of the steel, concrete in compression and concrete in tension respectively;

$n = \frac{E_c}{E_t}$;

$m = \frac{E_s}{E_t}$:

f = stress in metal reinforcement;

c = compressive stress in outer fibre of concrete;

t = tensile stress in outer fibre of concrete.

Reinforcement is supposed to be in the tension flange alone.

E_c and E_t are measured at the stresses c and t.

The values of x, u and p are ratios; p and u are at the control of the designer, while x depends on p, u, n and m; n and m are fixed by the quality of the materials, and they change during flexure with the varying values of c, f and t; that is, the modulus of elasticity of the concrete varies with the stress at which it is measured. For practical purposes of computation, however, the constant values of n and m may be used appropriate to the point A and to the point of cracking shown in Fig. 1.

On the assumption of plane cross-sections during flexure, we may determine the ratio of c to t and f to t as follows:

$$c = \frac{t\,n\,x}{1 - x}. \qquad (1)$$

$$f = \frac{t\,m\,(u - x)}{1 - x}. \qquad (2)$$

The values of $\frac{c}{t}$ and $\frac{f}{c}$ are shown in Figs 3 and 4.

Next, to locate the neutral axis; that is, to determine the value of x, we may equate the forces of tension and compression on the cross-section, assuming, as before, that the stress-strain diagrams are arcs of parabolas. Thus:

$$\tfrac{2}{3}\,c\,x = \tfrac{2}{3}\,t\,(1 - x) + p\,f. \qquad (3)$$

Inserting the values of c and f obtained above, we obtain the following quadratic:

$$\tfrac{2}{3}\,x^2\,n = \tfrac{2}{3}\,(1 - x)^2 + p\,m\,(u - x).$$

Solving the quadratic we have:

$$x = \frac{-\left(\frac{4 + 3\,p\,m}{2}\right) + \sqrt{4\,n + \frac{9}{4}\,p^2\,m^2 + p\,[6\,m\,(u\,[n - 1] + 1)]}}{2\,(n - 1)} \qquad (4)$$

Having obtained x, we may compute c and f, and finally obtain the moment of resistance of the section. Taking moments about the neutral axis, we have:

$$M = t\,b\,h^2 \left(\frac{5}{12} (1-x)^2 + \frac{5\,n\,x^3}{12\,(1-x)} + p\,\frac{(u-x)^2}{1-x}\,m \right); \qquad (5)$$

The expression in brackets is shown as K in Figs. 3 and 4 except that p is a per cent in latter, and not a ratio, as in Eq. 5.

No useful development will result from the substitution in Eq. 5 of the value of x, obtained in general terms in Eq. 4. In practical computations n,* m, u and p are given; x is then computed from (4); c and f computed from (1) and (2); finally the moment of resistance is computed from (5).

The process of computation is simplified by the fact that h and x are the same for equal products of p m.

The equations given above are to be applied to compute the load at the point A. At the load corresponding to the cracking of the concrete in the tension face, these equations should be modified to correspond with the fact that the stress-strain diagram for the concrete in tension is more nearly a rectangle than a parabola. The difference, however, between the results at the time of the appearance of the crack due to the assumption of a rectangle or a parabola is small. With proper values of n and m the equations may be allowed to stand.

For 1-2-4 stone concrete the values of m = 100 and n = 12 will give the load at first crack. For 1-5 gravel concrete, the values of m = 130 and n = 16 may be taken.

When, however, the crack having formed itself, extends throughout the lower region of the cross-section, the equations must be modified by the omission of the effect of the tensile forces due to the resistance of the concrete under tension.

We have then:

$$\tfrac{2}{3}\,c\,x = p\,f \text{ or, } p\,\frac{E_s}{E_c}\,(u-x) = \tfrac{2}{3}\,x^2, \ldots \ldots\ldots\ldots \qquad (4)^1$$

which serves to locate the neutral axis. When f is assumed to be the elastic limit of the reinforcing metal c may be computed. As noted above, in the stone-concrete beams tested by the writer, the elastic limit of the iron was reached before the concrete failed in compression.

The resisting moment of the section is then

$$M = bh^2 \left\{ \frac{5}{12} c x^2 + p f\,(u-x) \right\} \ldots\ldots\ldots\ldots\ldots\ldots (5)^1$$

---

* If $n = 1$, then $x = \dfrac{2 + 3\,p\,m\,u}{4 + 3\,p\,m}$

CROSS-BENDING TESTS ON BEAMS OF REINFORCED CONCRETE.

PROF. MALVERD A. HOWE, ROSE POLYTECHNIC INST., TERRE HAUTE, IND.

Presented April 6, 1904.

Through the courtesy of the St. Louis Expanded Metal Fire-Proofing Company, of St. Louis, Missouri, I am able to give you the results of a series of tests recently made at the Rose Polytechnic Institute, under my direction, upon beams of concrete reinforced with corrugated steel bars.

The object of the test was to obtain the actual strength in cross-bending of full size concrete beams reinforced with corrugated bars, according to the formula of Mr. A. L. Johnson. It was afterwards decided that, in conjunction with the determination of the cross-bending stength, there should also be recorded the deflections and the movement of the neutral axis.

In order that the concrete and steel should represent products likely to obtain in practice, Atlas cement, bank sand, crushed rock and corrugated steel bars were purchased in the open market. The mixing was done by a local contractor of experience, with his own gang of men and in the manner he ordinarily employed.

The quality of the materials was in general good. The cement was satisfactory in every way. The sand, while containing some "dirt" in the form of yellow clay, was a fair representation of bank sand used in Terre Haute. The crushed limestone was in two parts, one coarse and the other fine, the two mixed forming the run of the crusher. The coarse stone would pass a screen of one and one-half inch mesh and would stop at one of one-half inch mesh; and the fine stone would all pass a screen of one-half inch mesh. The corrugated steel bars, when tested, showed an elastic limit of about 60,000 lbs., and an ultimate strength of about 100,000 lbs. The areas of the bars were, in general, as advertised with the exception of the ¾-inch bars, which were found to be about 20 per cent under size.

The proportion of cement, sand and stone was practically one of cement to seven parts of sand and stone.

The mixing was done on a concrete floor. The dry materials were placed in layers in the following order, stone, sand and cement. The mass was then turned twice dry and then twice wet, the water being introduced from a hose. The mixture was then shoveled into barrows and wheeled to the molds and dumped over the sides. Four to six inch layers were deposited the full length of the molds and tamped with iron tamping bars. The first two batches were moderately dry and the others pretty wet and required but little tamping.

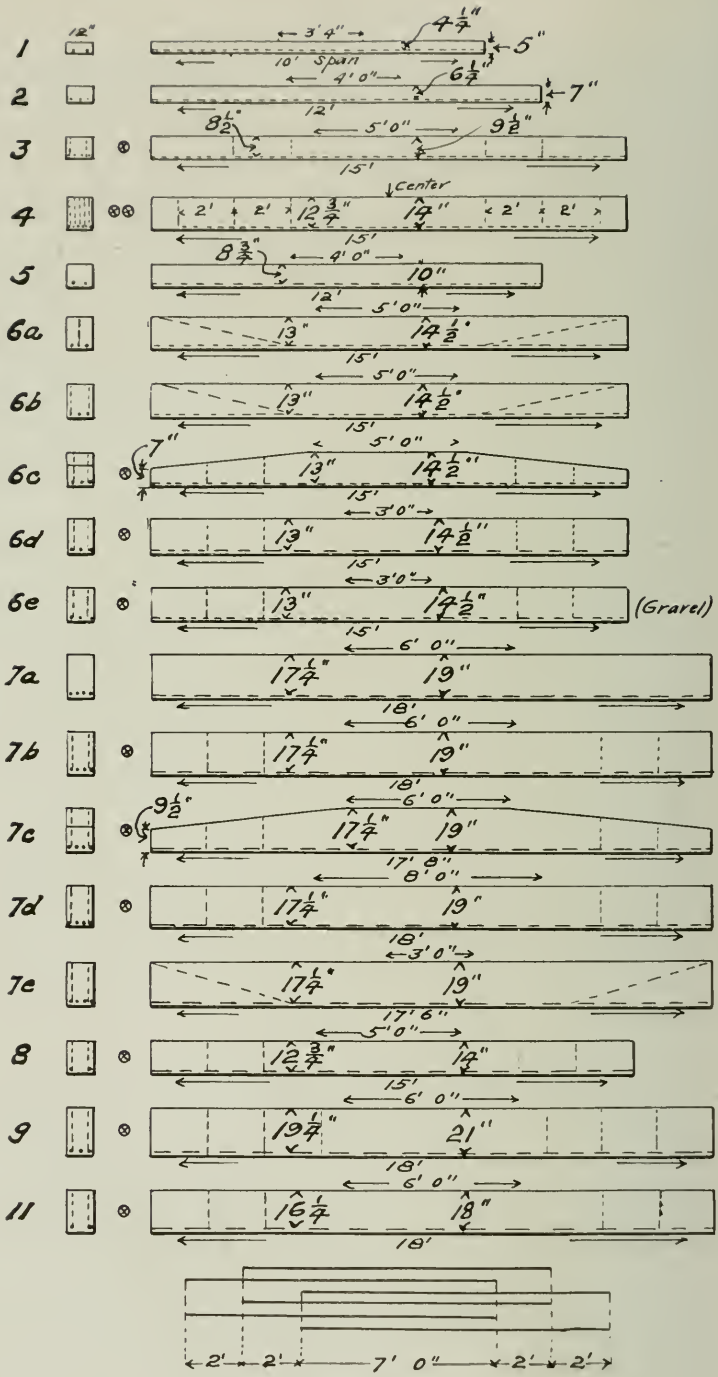


PLATE 1.

* Vertical ½ inch corrugated bars placed as shown and not attached to horizontal bars.
** The ends of the reinforcing bars bent as shown in sketch below beam No. 11.

Very rigid knock-down moulds were used and no special means employed to obtain a smooth surface on the concrete, other than that given by mill finished lumber. The moulds were not wet before being filled and were not removed until the beam was to be tested. The beams were seasoned in basement rooms of a temperature of about 65 degrees F.

Table I. shows the general dimensions of the beam and the arrangement of the steel bars. Although the beams were widely different in the dimensions of length and depth, yet all were designed on the same basis, the same percentage of steel being intended for each beam.

From each batch of concrete two prisms, 6 x 6 x 9 inches, were made for compression tests. Unfortunately, however, so little care was taken in filling the moulds that the specimens were very porous and non-homogeneous; consequently the results of the compression tests were of little value.

In testing a beam the ends were supported in stirrups, free to swing on knife edges at about the center line of the beam, as shown in Fig. 1. Two equal, concentrated loads were applied, symmetrically about the center of the beam, through knife edges in rolling seats, thereby producing a constant bending moment between the points of application of the loads (excepting the variable moment

TABLE I.

MAKE-UP AND DIMENSIONS OF BEAMS.

Beam.	Made 1903.	Concrete Batch.	Number and Size of Steel Bars.	N'm'nal Areas	Actual Net Areas of Steel.	Dist. Ctr. Steel below top of Beam *d*.	Total Depth of Beam.	Breadth of Beam.	Length of Beam Over All.
			IN.	SQ. IN.	SQ. IN.	IN.	IN.	IN.	FT. IN.
1	Oct. 13	1	2–½	0.36	0.36	4¼	5	12	12 0
2	Oct. 13	1	3–½	0.54	0.54	6¼	7	12	14 0
3	Oct. 13	2-3	4–½	0.72	0.72	8½	9½	12	17 0
4	Oct. 14	9	6–½	1.08	1.08	12¾	14	12	17 0
5	Oct. 14	5	2–¾	0.74	0.60	8¾	10	12	14 0
6*a*	Oct. 14	6	3–¾	1.11	0.90	13	14½	12	17 0
6*b*	Oct. 14	6	3–¾	1.11	0.90	13	14½	12	17 0
6*c*	Oct. 14	8	3–¾	1.11	0.90	13	14½	12	17 0
6*d*	Oct. 14	6-7	3–¾	1.11	0.90	13	14½	12	17 0
6*e*	Oct. 15	12	3–¾	1.11	0.90	13	14½	12	17 0
7*a*	Oct. 13	3-4	4–¾	1.48	1.20	17¼	19	12	19 6
7*b*	Oct. 13	4	4–¾	1.48	1.20	17¼	19	12	19 6
7*c*	Oct. 14	9-10-11	4–¾	1.48	1.20	17¼	19	12	19 6
7*d*	Oct. 14	7	4–¾	1.48	1.20	17¼	19	12	19 6
7*e*	Oct. 14	9	4–¾	1.48	1.20	17¼	19	12	19 6
8	Oct. 13	2	2–⅞	1.10	1.06	12¾	14	12	17 0
9	Oct. 13	5	3–⅞	1.65	1.59	19¼	21	12	19 6
11	Oct. 14	8	2–1	1.40	1.40	16¼	18	12	19 6

TABLE II.

MAXIMUM LOADS AND MOMENTS.

Beam.	Age in Days.	Span *c-c* End Support.		Dist. between Loading Points.		Total Weight of Beam.	Total Max. Load.	Load when Comp. Failure was marked. Load Fall'ng off fr'm Max.	Max. Moment 1000s of in Lbs.	Theor'tic'l Moment Johnson's Formula.	See Foot Note
		FT.	IN.	FT.	IN.	LBS.	LBS.	LBS.	LBS.	LBS.	
1	74	10	0	3	1	825	4200	3400	94.3	80.6	
2	76	12	0	4	0	1150	8100	5100	212.2	174.2	
3	72	15	0	5	0	2000	12100	.....	402 7	322 2	
4	73	15	0	0		2860	19400	....	929 8	725.0	1
5	71	12	0	4	0	1700	11900	....	311.9	283.0	
6*a*	71	15	0	5	0	2935	18300	....	607.2	625.0	
6*b*	69	15	0	5	0	2950	19325	16500	638 3	625.0	
6*c*	115	15	0	5	0	2450	20400	19100	666.3	625.0	
6*d*	29	15	0	3	0	2960	15500	....	616 8	625.0	2
6*e*	29	15	0	3	0	3125	17000	.....	692.0	625 0	3
7*a*	78	18	0	6	0	4450	30000	28500	1189.4	1121.0	
7*b*	78	18	0	6	0	4325	29000	23600	1152.0	1121.0	
7*c*	70	17	9	6	0	3800	30100	. . ..	1142.9	1121.0	
7*d*	68	18	0	8	0	4450	29900	....	1006.4	1121 0	4
7*e*	77	17	6	3	0	4200	22800	....	1090.7	1121.0	5
8	77	15	0	5	0	2900	23300	22300	756.5	725.0	
9	77	18	0	6	0	4850	34800	....	1373.7	1652.6	6
11	75	18	0	6	0	4225	29000	25700	1149.3	1177.8	

[1] 14000 applied 6 ft. 6 in. Removed and loaded in center. Failed at load.

[2] Failed by Comp. near center.

[3] Failure same as 6*d*. Made of gravel from pit.

[4] Several repetitions of load. Failed by shearing.

[5] Repeated loads. Failed by shearing.

[6] Failed by shearing.

produced by the weight of the beam). The rolling seats for the knife edges were supported by ¾ x 4-inch steel plates, bedded in plaster of paris on top of the beam. This arrangement is shown in Fig. 2, for beam No. 8.

The vertical deflections were read directly from a scale on the side of the beam at the center by means of a silk thread fastened opposite the knife edges of the end stirrup.

Measurements for the determination of the relative positions of neutral axis, under different loads, were made in the following manner: Four yokes were fastened to the beam by conical points in the positions shown in the photograph of Beam No. 8, Fig. 2. These were connected by wooden strips, as shown, and the relative positions of these determined at the top and bottom by means of a silk cord fastened to one and running over a graduated arc fastened to the other. The first readings of the arcs were taken under a small initial load. The data obtained can best be illustrated by giving the complete notes for Beam No. 8.

BEAM NO. 8. TESTED DECEMBER 29, 1903.

Span, c–c of end stirrups.... ....15 ft. 0 ins.
Span, c–c of concentrated loads .... 5 ft. 0 ins.
Distance, c–c of extensometers. ... . 6 ft. 0 ins.
Length, out to out, of beam............ ....17 ft. 11 ins.
Weight of beam............ ... . 2900 lbs.
Vertical distance between conical points of extensometer yokes.........12¾ ins.
Vertical distance between graduated arcs on extensometers....... ... 27⅛ ins.
(Lower arc opposite lower conical point.)

Total Con. Load. *Lbs,*	Ver. Deflection at Centre. *mm.*	Upper Arc.	Lower Arc.	Remarks.
1100	44.2	142.6	2 4	
2100	44.8	141.4	2.6	
3000	45.0	139.8	3.2	
4000	55.6	137.4	4.2	
5000	46.2	133.8	5 8	
6000	47.8	128.2	8.4	
7000	48.6	124 4	10.2	Crack 12 ins. E of W load.
8000	49.8	120 0	13.0	Crack 6 ins. E of Center, 8 ins. W of Centre, 14 ins. W of Centre, 4 ins. E of W load, 18 ins. E of W load.
9009	50.8	115 6	15.0	
10000	52.0	111.4	17.2	Crack under W load, shear crack 2 ins. above bottom, extending 18 ins. E of W load.
11000	53.2	108.8	19.2	Crack 6 ins. W of E load.
12000	54.4	107.2	21.6	Crack 12 ins. W of W load.
13000	55.6	90.4	23.6	Crack under E load 15° with vertical.
14000	56.8	93.4	25.6	
15000	58.0	89.2	27 6	
16000	59.2	84.6	30.0	Crack 6 ins. W of Center.
17000	60.6	80.0	32.0	
18000	61.8	75.4	34.0	
19000	63.0	70 0	36 4	
20000	64.4	65 0	37.4	Longitudinal crack 5 ins. above bottom at both ends.
21000	65.9	59.4	40.4	
22000	67.5	53.4	43.2	
2 000	69.9	46.8	45.8	
23200	95.0			
23300	105.0	(Max. Load).		
22765	135.0			
22000	145.0	(Comp. failure 30 ins. W of centre).		

The general make-up of each beam is clearly shown by Plate I. and Table I. Table II. gives the result of the tests in terms of the loads, bending moments and mode of failure. Table III. was computed by Johnson's Formula using the value of y_1 obtained from the experiments. This value was, in most cases, found graphically. For four beams, however, it was computed and the resulting values plotted. These lines showed that at the commencement of the loading the neutral axis was below the centre of the beam. As the load increased in magnitude, the axis moved upward very rapidly until cracks commenced to appear on the bottom of the beam; then the axis remained approximately in the same position as long as the concrete did not show signs of failure in compression, as indicated by the drop of the scale beam. At or near the end of the

TABLE III.

FIBRE STRESSES ACCORDING TO JOHNSON'S FORMULA AND EXPERIMENTAL y_1.

Beam.	Center of Steel Below Top of Beam. *d*	Neutral Axis Below top of Beam. y_1	Max. Stress in Concrete in Comp. Lbs. per Sq. inch.	Concrete in Tension Lbs. per Sq. inch.	Steel in Tension. Lbs. per Sq. inch.	Batch in Top of Beam.	See Foot Note
	IN.						
1	4¼	0.45*d*	1700	170	66000	1	
2	6¼	0.45*d*	1900	190	66000	1	1
3	8½	0.38*d*	2300	230	64000	3	2
4	12¾	0.34*d*	2500	250	64800	9	3
5	8¾	0.42*d*	1500	150	60500	5	
6*a*	13	0.37*d*	1500	150	51000	6	
6*b*	13	0.37*d*	1500	150	54000	6	4
6*c*	13	0.42*d*	1400	140	58300	8	
6*d*	13	....	....	....	....	7	5
6*e*	13	....	....	....	....	12	5
7*a*	17¼	0.39*d*	1600	160	57000	4	6
7*b*	17¼	0.53*d*	1600	160	53500	4	7
7*c*	17¼	0.36*d*	1600	160	53500	11	
7*d*	17¼	0.35*d*	1400	140	47600	7	8
7*e*	17¼	0.35*d*	1600	160	52200	9	8
8	12¾	0.36*d*	2000	200	54000	2	
9	19¼	0.40*d*	1400	140	45000	5	9
11	16¼	0.39*d*	1700	170	50500	8	10

[1] Reset upper arc at 6000 lbs.

[2] Cord of upper arc touched at 7000 lbs.

[3] Center load, hence axis may not be correctly located.

[4] Repeated loading.

[5] No records for y_1.

[6] Cord of upper arc touched at 25000 lbs.

[7] Cord of lower arc touched at 6000 lbs.

[8] Repeated loads and failed in shear.

[9] Failed in shear.

[10] Upper cord touched at 16000 lbs.

TABLE IV.

FIBRE STRESSES ACCORDING TO COMMON THEORY AND EXPERIMENTAL y_1.

Beam.	Max. Comp. in Concrete Lbs. per Sq. in.	Tension in Concrete.	Tension in Steel Lbs. per Sq. in.	REMARKS.
1	2120	Concrete assumed to take no tension.	76500	See Table III.
2	2380		76500	
3	2870		74300	
4	3100		75500	
5	1900		56000	
6*a*	1900		59300	
6*b*	1900		62500	
6*c*	1750		67700	
6*d*	....		....	
6*e*	....		... .	
7*a*	2000		66400	
7*b*	2000		62000	
7*c*	2000		62000	
7*d*	1800		55500	
7*e*	2000		60000	
8	2500		64200	
9	1750		52200	
11	2100		58100	

experiment the axis, sometimes, not always, dropped suddenly. (See Figs. 3, 4 and 5.)

The values of y_1 are probably in error, but not enough to be of any practical importance. The travel of the neutral axis is correctly obtained by the methods employed (assuming that a plane section remains plane after its distortion of the fibres), but its exact location in reference to the centre of the beam is not known, as the experiments were commenced under an initial load including the weight of the beam.

Table IV. was computed, using the same values of y_1 as employed in Table III., under the assumption that the concrete resisted no tension, and that in compression the distortion of the concrete was proportional to the stress producing it.

Throughout the entire series of experiments, the curves of deflection and extension showed a marked similarity. The appearances after tests of six of the eighteen beams tested, and the plottings of the result obtained for three of the beams are very clearly shown in Figures 6 to 14 inclusive, and illustrate the general characteristics of the beams. These diagrams were prepared by Mr. T. L. Condron, M. W. S. E., from the original records of the tests. By plotting the upper and lower extensometer readings in their correct relative position as regards the beam, and connecting the corresponding points with rays, the intersection of these inclined rays with the initial vertical line, determines the location of the neutral axis at each stage of the test. It will be noted that these diagrams show in another way the same movement of the neutral axis as do Figs. 3 to 5 inclusive, already referred to. The distance of the neutral axis above the plane of reinforcing is given for the highest position of the neutral plane and not for the position at the time of maximum load. In these diagrams the deflections are given in decimals of an inch. The extensometer readings are plotted as observed. Ten divisions on the extensometers equaled 0.03932 inches or approximated 255 divisions to the inch.

The small circles and letters on the deflection curves indicate where fine hair cracks were first observed in the concrete on the tension sides of the beams and the relative position of these first cracks is shown on the small sketches on each diagram.

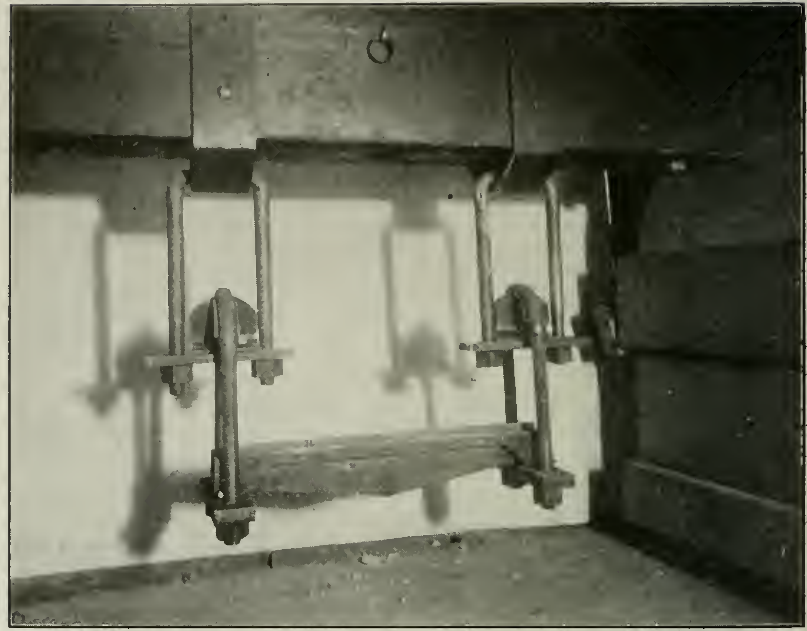
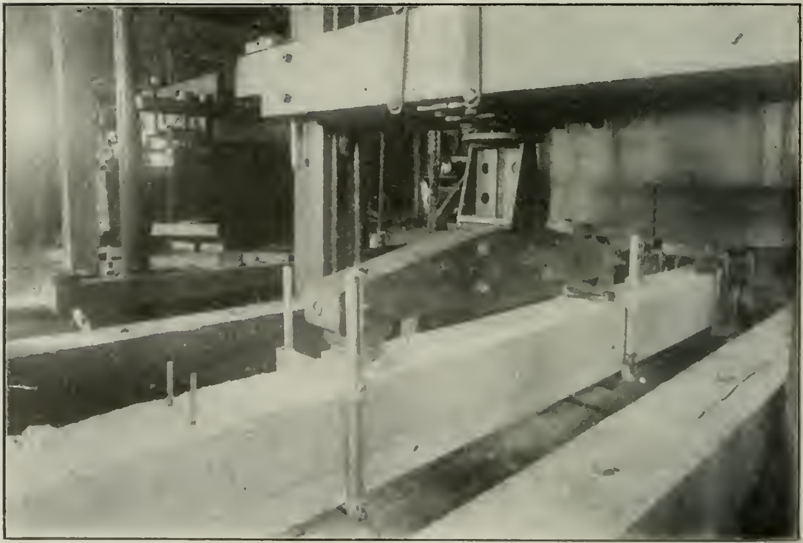


Fig. 1.



Fig, 2.

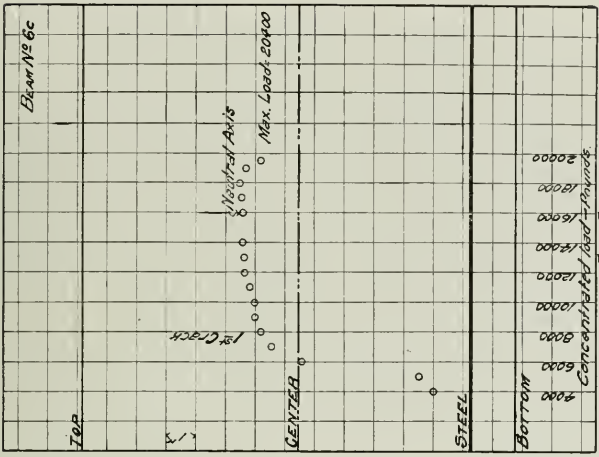


FIG. 5

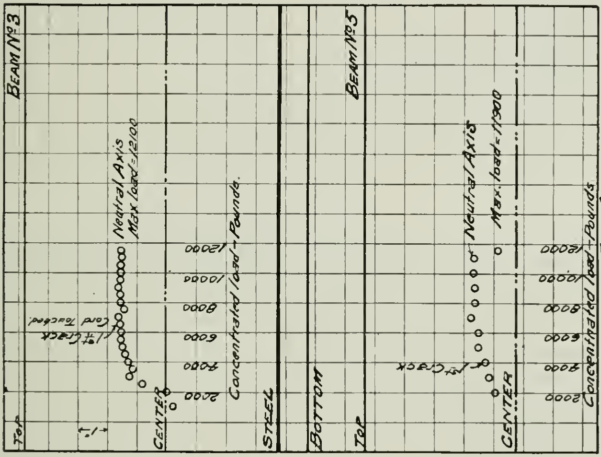


FIG. 4

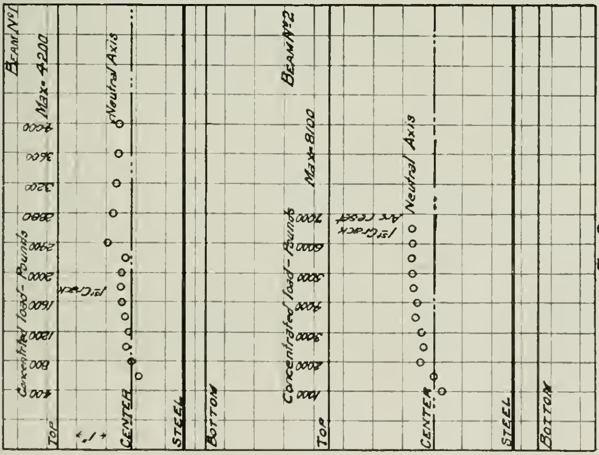


FIG. 3

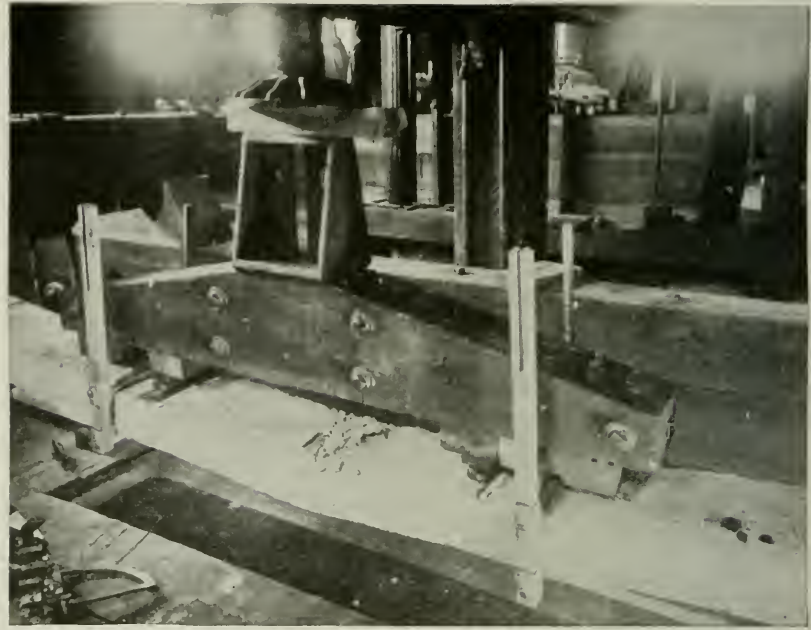


Fig 6, Beam No. 1. Depth 5 inches, Span 10 feet.

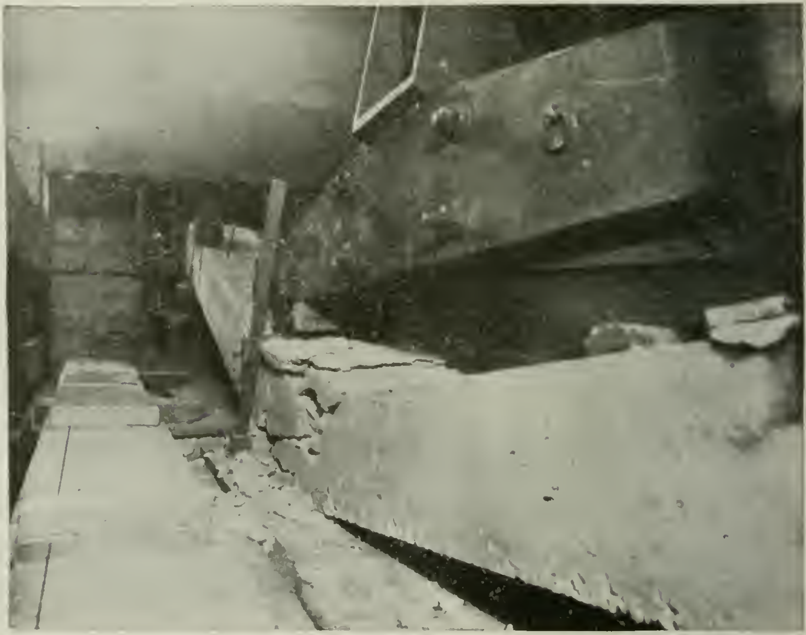


Fig. 7, Beam No. 3. Depth $9\frac{1}{2}$ inches, Span 15 feet.

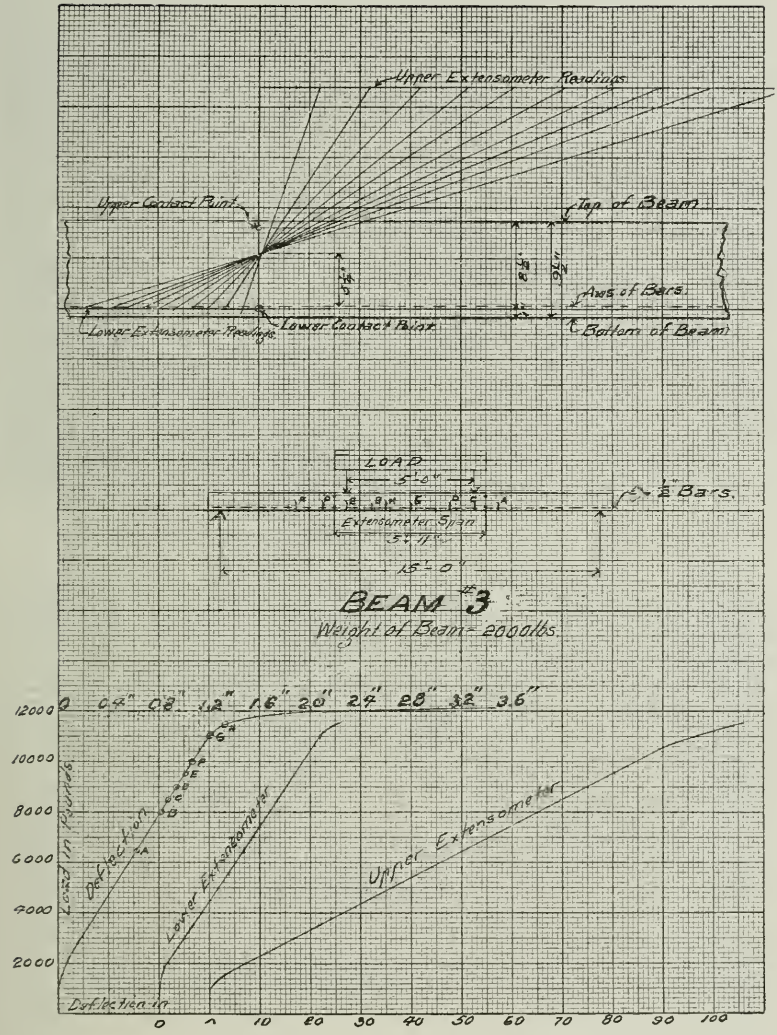


Fig. 8. Location of the Neutral Axis and the Curves of Deflection and Extensometer Readings, Beam No. 3.

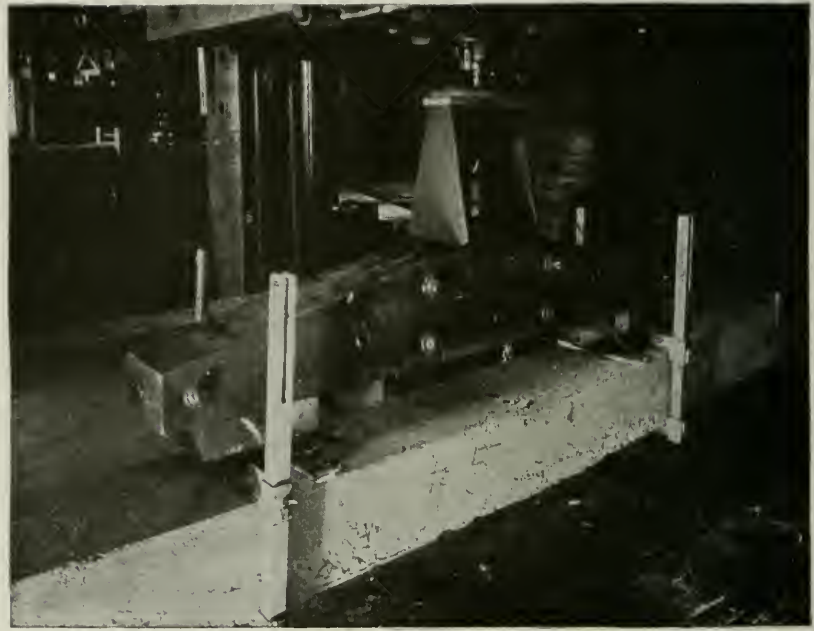


Fig. 9, Beam No. 5. Depth 10 inches, Span 12 feet.

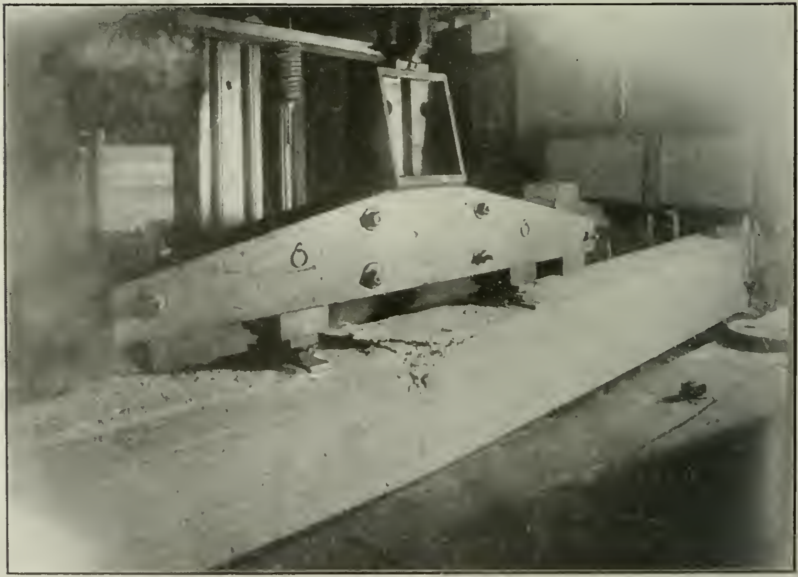


Fig. 10, Beam No. 6e. (Gravel.) Depth 14½ inches, Span 15 feet.

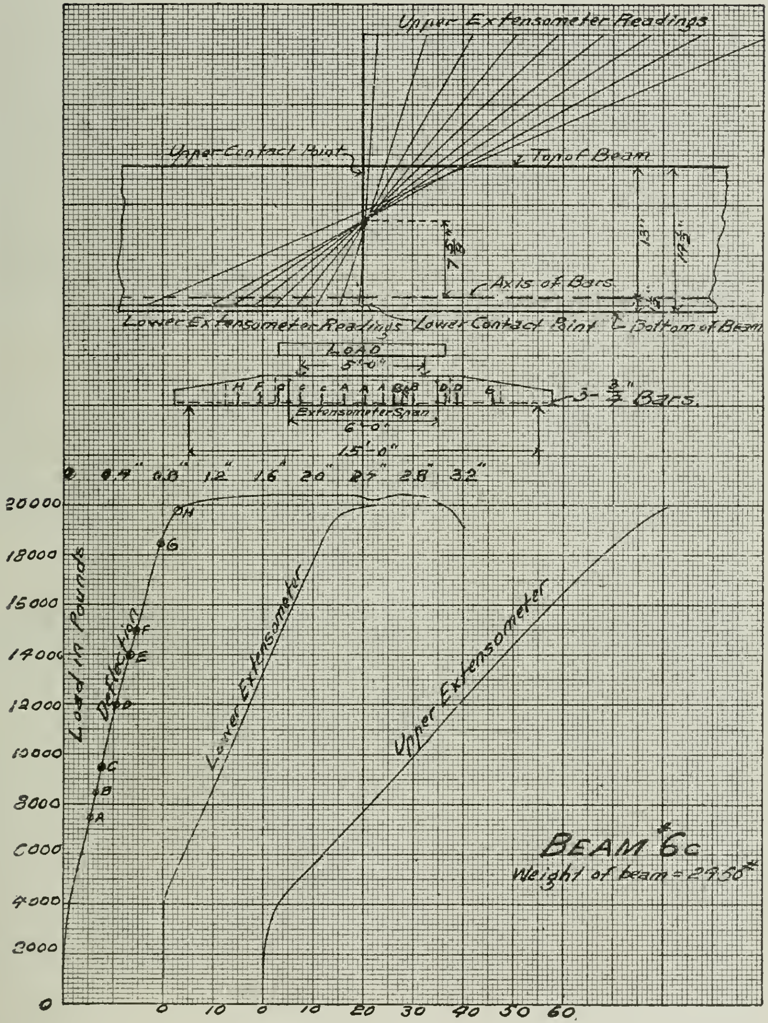


Fig. 11. Location of the Neutral Axis and the Curves of Deflection and Extensometer Readings, Beam No. 6c.

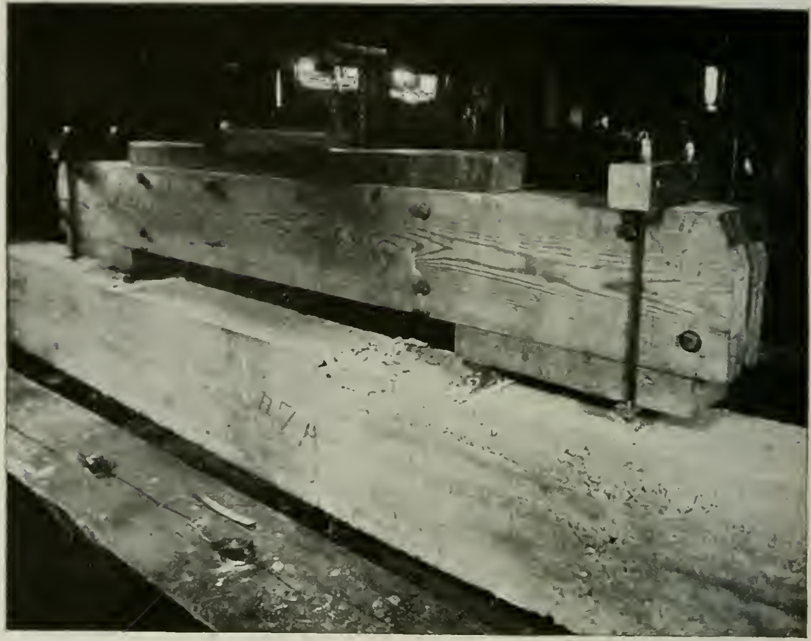


Fig. 12, Beam No. 7a. Depth 19 inches, Span 18 feet.

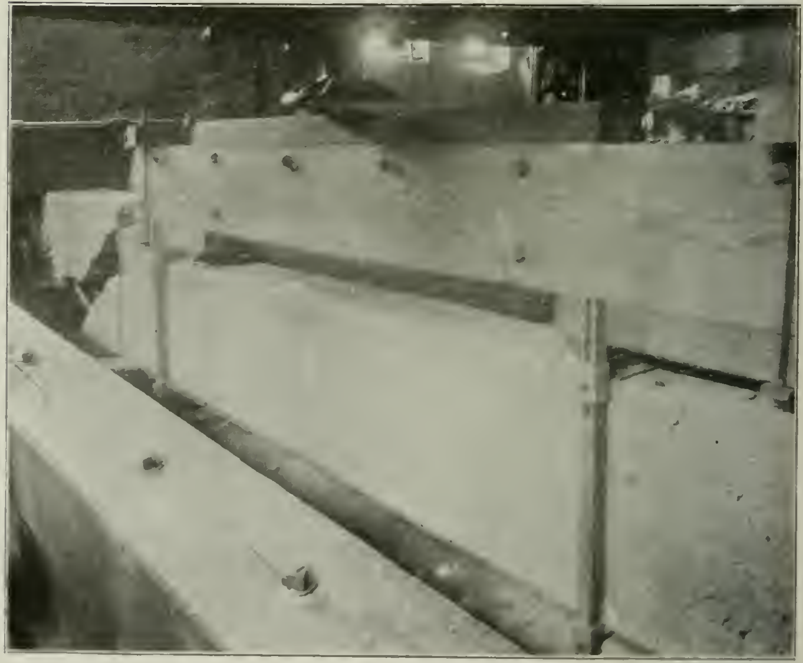


Fig. 13, Beam No. 9. Depth 21 inches, Span 18 feet.

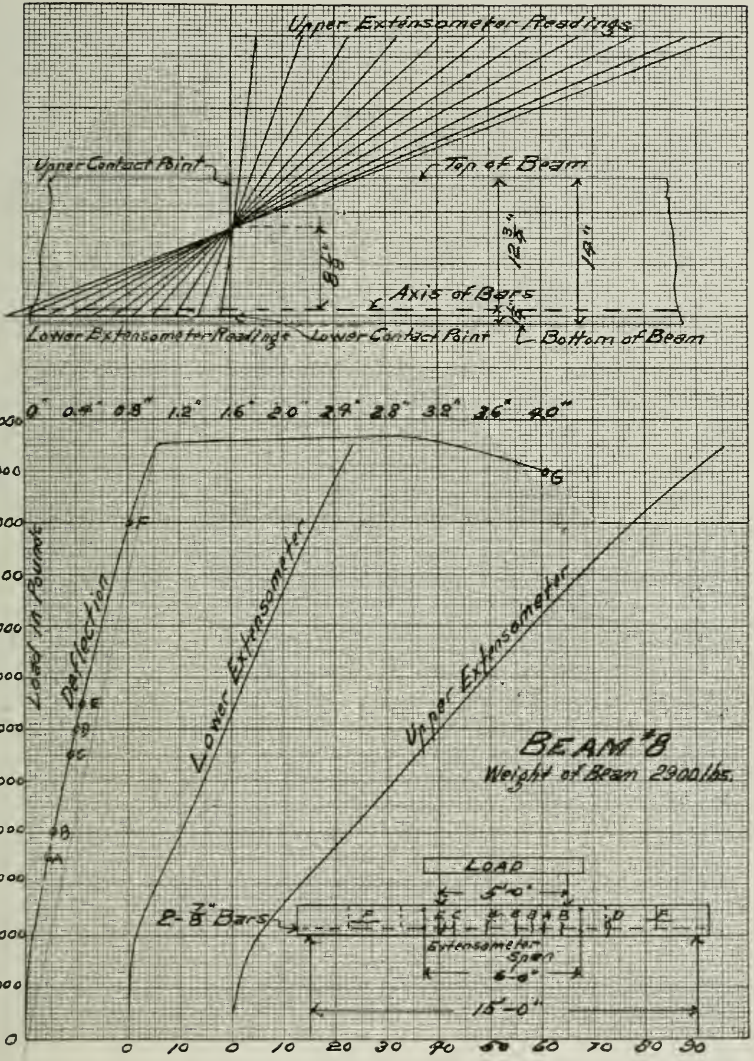


Fig. 14. Location of the Neutral Axis and the Curves of Deflection and Extensometer Readings, Beam No. 8.

DISCUSSION.

Mr. J. W. Schaub (*by letter*)—The crack which sometimes appears near the end of a reinforced concrete beam has been widely designated as a shear crack, or a crack due to end shear. This crack is not due to a shear any more than a crack near the middle of the beam is caused by shear. The crack is simply due to the failure of the concrete in tension, and when this crack occurs near the end of the beam, it is invariably due to a slipping of the metal in the concrete. This slipping starts at the ends, when the concrete alone cannot carry the tension, and fails. To be sure, there is a longitudinal shear between the concrete and the metal, near the ends of the beam, and this is the cause of the slipping, but the crack which starts on the tension face is not caused by a shearing on the concrete.

If the factor of safety should be fixed with reference to the appearance of the first crack, I fail to see how a high tension steel will augment the strength of the beam. To be sure, a high steel may delay the opening of this crack, but a beam which shows a crack has failed, and can find no place in a structure which is designed to do its work inside of the elastic limits of its materials.

Assuming a reinforced concrete beam in tension,

let Δ equal the extension of a unit of length;
let p denote the stress;
let l denote the length;
let E denote the modulus for steel = 30,000,000.

$$\text{Then } \Delta = \frac{pl}{E}, \text{ whence } p = \frac{\Delta \times 30{,}000{,}000}{l}$$

The extension Δ has been found by all experimenters to be, within safe limits, not more than $\frac{1}{1000}$. Some results have shown $\frac{1}{800}$, but they are unusual. Then for the condition of the first crack we have:

Assuming $\Delta = \frac{1}{1000}$; and l = unity; then $p = \frac{30{,}000{,}000}{1000}$ = 30,000 pounds.

This is the stress on the steel, for this condition, the concrete having been eliminated owing to the crack. Therefore, as far as the first crack is concerned, it makes no difference what the elastic limit may be, the stress on the steel is near 30,000 pounds. It is usually taken at 36,000 pounds in order to be safe, and provide for a greater extension than assumed.

Mr. L. K. Sherman (*by letter*)—Prof. Hatt gives figures for the Modulus of Elasticity of concrete. I do not think that it is correct to use a constant value of E for all stresses in reinforced concrete.

With concrete, the stress is not proportional to the strain.

Hence the modulus of elasticity is not a constant. E varies with the loading and is greater with the lesser stress.

Experiments by C. Bach on the elasticity of concrete (See Journal of W. S. E., vol. I, page 84) show this law to good advantage.

Now as E is used in all concrete-steel beam formulæ, it seems to me that when we wish to determine stresses under working loads, we should use the value of E as found by experiments made under working stresses.

Similarly, when we wish to proportion a concrete-steel beam for ultimate loading, we should use the value of E that corresponds to an ultimate load. This value of E will be the least.

A. L. Johnson (*by letter*)—The speaker does not agree with the statements just made by Mr. Schaub. He says that in Fig. 1 the crack at the end of the beam may be illustrated by the lines *a c*. beginning as a tension failure at *a*, and that this is shown in the photographs of Professor Howe's tests. This is not the case, however. The crack began as a horizontal shear crack at *b* and followed the line *bc*, the part *ab* afterwards dropping off. At the end of a beam, the elongation on the bottom fibre is so slight that a crack at *a* is exceedingly improbable unless all the tension is thrown into the concrete alone, the bar pulling out of its anchorage. With plain bars this is a common occurrence. In all the tests made last year at the University of Wisconsin the beams with plain bar reinforcement failed by the slipping of the bars at the end of the beams.

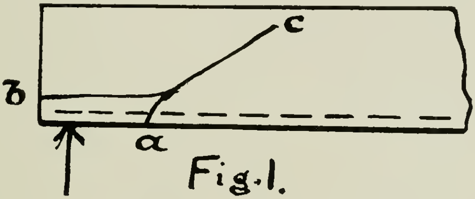


Fig. 1.

In such reinforcements as used in the tests made by Prof. Howe, however, failure, if by shear at all, will be along the plane above the metal reinforcement and then upward as shown by the line *bc* in Fig. 1. Where a center load is used however, failure along the line *ac* is a common occurrence, but in this case it is near the loading point.

Mr. Schaub also asks why we should use a higher limit of elasticity in the metal reinforcement than just sufficient to develop, inside this limit, the extensibility of the armored concrete, which he says has been shown to be .0010; which corresponds to an elastic limit in the steel of 30,000 pounds per square inch.

To this the speaker would reply that Mr. Schaub's argument is correct, but his limit of the extensibility of the concrete is in error.

The extensibility of the concrete in the Terre Haute tests, as measured by an extensometer on the bottom of the beams, was variable and was considerably affected by the degree of dryness of the concrete. But one of the beams, No. 2, showed a proportionate elongation at the first noticeable crack of .00153 and several of the beams had only very slight cracks at .0018. The first value corresponds to an elastic limit in the steel of 45,900 pounds per square inch and the second value, to 54,000 pounds per square inch. In structures built in the open air much more extensibility will be obtained in the concrete than in those under cover.

Under these circumstances therefore, the speaker considers a high elastic limit very desirable, warranting considerable extra expense for the metal, to obtain it. As a matter of fact, however, it costs no more than low elastic limit material. It must be remembered also that in steel-concrete structures the ultimate strength of the structure should be taken at that load that develops the elastic limit in the metal reinforcement. By using a small percentage, 0.75 per cent, for example, of soft steel reinforcement it is possible to develope, with good concrete, considerably more than the elastic limit stress in the steel, even breaking the latter entirely apart, if the concrete is of sufficient crushing strength. Whether cracks have developed in the concrete or not, and whether sections, plane before bending, are now plane or not, there is one condition that is true in any case; that is, that the total tension below the instantaneous neutral axis is equal to the total compression above that axis.

Now if the concrete below the neutral axis has been ruptured, which is of course the case if the metal has passed its elastic limit, and if the percentage of metal is small, then the neutral axis may rise very close to the top of the beam and still provide enough compression strength in the concrete to equal the tensile strength of the steel. This puts the latter at considerable distance from the axis and hence, slight deflections of the beam produce large stretches in the metal, which might easily amount, at the section of maximum stress, to the full elongation of which the metal was capable at rupture. In this case the carrying capacity at rupture would of course be somewhat more than it would be at the elastic limit of the metal; but the cracks in the beam would be so large and numerous as to soon lead to the destruction of the beam and in the speaker's judgment it would be wholly improper to evaluate the capacity of the beam beyond that at the elastic limit of the metal. Beams reinforced in the above manner, with only one half the proper quantity of metal reinforcement, will of course deflect greatly before developing the maximum load, and would therefore develop considerable ultimate resilience. But there is nothing so desirable in this quality as to warrant paying anything for it. The elastic resilience is of some importance, but this would be small with such reinforcement.

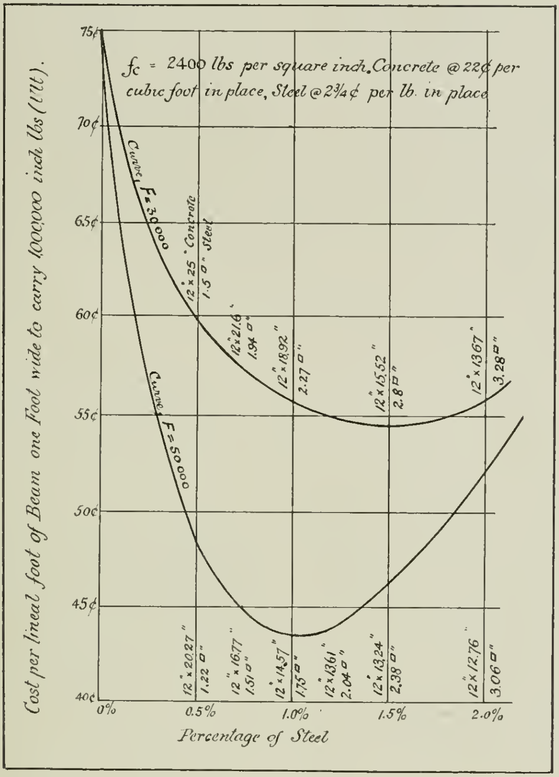


Fig. 2.

The most economical percentages of metal of low and high grades are shown in Fig. 2. From this it will be seen that the most economical beam reinforced with material having an elastic limit of 50,000 pounds per square inch costs, at the prices shown, only about two thirds as much as the most economical beam of the same strength where soft steel is used. The most economical beam with the high grade material is with the one per cent reinforcement; with the low grade material, 1.5 per cent reinforcement. This latter percentage has been separately discussed by Professor Hatt by his formula and the same result, i. e., 1.5 per cent arrived at as that most economical to use where soft steel is employed.

For the conditions existing in practice where the maximum load is more or less uniformly distributed, the beam reinforced with high elastic limit material has another advantage over the soft material in that there is less liability to shear. It has a greater liability to shear when tested by two loading points some distance apart, as is usually the case in laboratory tests. This is because at the elastic limit the tension cracks will be nearer the support, giving less anchorage for the bar, than where double the quantity of low elastic limit material is employed.

Two of the tests reported by Professor Howe, No. 7-d and No. 9, failed in this manner at about nine-tenths the full theoretical moment load. At this time there were fine cracks some little distance outside the loading points. Dividing the stress on the bars at the section of crack nearest the support, by the horizontal area of the beam from there to the end, and then multiplying by two—as the maximum shearing stress at the section would be probably double the average—the writer got approximately 300 pounds per square inch shearing stress in these beams at the time of failure, which is probably all that the concrete was capable of standing.

Such a shearing stress is entirely different from those ordinarily considered, and has little existence in actual practice. Laboratory tests, therefore, to be of reliable practical value, should be made with as near a uniform load as possible.

With such a load the shearing stress will be of the ordinary calculable kind and will be less with the high elastic limit reinforcement, inasmuch as the material requires a somewhat greater depth of concrete, which of course reduces the shearing intensity.

There is one point that the speaker would call attention to in connection with Professor Hatt's formulae. His general equation for the location of the neutral axis, $\frac{2}{3}cx = \frac{2}{3}t(1-x) + pf$ is the only true one for the ultimate value of c, the compressive stress on extreme fibre. Hence the general equation for the moment of resistance is, after all, not a general equation, but applicable only to the full load of the beam. Professor Hatt assumes that the compressive stress diagram for the concrete is a parabola with its vertex at the end, or near the end of same. This is sufficiently correct for all practical purposes as the writer can testify from his own examination of such diagrams. The area of this whole diagram is two-thirds that of the enclosing rectangle according to the property of a parabola. But this is only true when the vertex of the parabola is on one of the sides of the rectangle. If we take the first part of the stress strain diagram which is what would be used for light loads, the area would be very close to one half the enclosing rectangle instead of two thirds of same. It seems to the speaker therefore that while his formulæ are of the correct form for the maximum load, and will give good results for this case by the insertion of readily determinable rational empirical coefficients, they are not of the correct form for light loads, and agreement with the tests can only be obtained by the insertion of artificial coefficients having different values for different degrees of loading. All of this trouble arises through not having the vertex of the curve at the origin of coordinates, as it is not otherwise practicable to get a relation between the area of the stress strain diagram and the compressive stress itself. If however the vertex of a parabola is put at the origin of coordinates we have the wholly artificial condition of an infinite modulus of elasticity at the beginning of the loading. This condition however exists but for a very short time and the speaker is of the opinion that it would be the best method even where the parabola is used. Professor Bach gives the following equation for the curve of the compressive stress diagram of concrete,

$$\triangle = \frac{1}{E} - S m$$

where $\triangle$ = proportionate shortening,
E = modulus of elasticity in kg per cm^2,
S = the stress in the concrete in kg. per cm^2,
and m = a coefficient depending upon the kind of concrete.

For different materials m varies, according to Professor Bach from 1.09 for 1:2½ of sand, to 1.15 for 1:2:5 limestone concrete. This equation is undoubtedly of a more nearly correct form than a parabola and has the advantage of not giving the absurd condition of infinite modulus at the origin. It is of course much more difficult to see, but by means of curves and tables its use could no doubt be made practical.

Generally speaking, however, we do not care to know what the deflections will be at certain minor loads, and this is about all the advantage we would secure from an ideal formula which so far certainly has not been devised. Our main interest is in the maximum capacity of the beam and for such case Professor Hatt's formulæ are as correct as it is possible to obtain.

The speaker is of the opinion, nevertheless, that it is perfectly feasible to obtain a formula that will be scientifically accurate for all conditions of loading and percentages of metal, and still be readily manipulated. In the meantime however, we are not suffering for the lack of it. Its scientific value would be great, but its practical value small.

Mr. J. T. Montgomery—I would like to know the form of the bar used by Prof. Hatt in his tests, and I would also like to know if he has made any tests for adhesion per square inch of surface ?

Prof. Hatt—Answering Mr. Schaub, I would say that my statement in the paper is as follows : "The higher the elastic limit of the steel the more one postpones the point of rapid increase of the width of this crack." There must be very fine hair cracks, even at very low loads. Certainly a crack cannot widen until the steel begins to stretch. It will not be a serious crack until the steel has reached its elastic limit.

In regard to the form of bars referred to by Mr. Montgomery: I use round bars entirely. I have made tests of adhesion plus friction and found they ran about 500 pounds per square inch of surface.

Mr. Schaub—There is one other point I would like to ask Prof. Hatt about, and that is in regard to the economical percentage of steel to use. I judge from his remarks that this was based on 1-2-4 concrete.

Prof. Hatt—Yes, you are correct in your assumption.

Mr. Schaub—The proper percentage for steel in 1-2-4 concrete is no doubt near 1.5 per cent; but, by increasing the depth of the beam about 50 per cent and using a 1-3-6 concrete, the proper percentage for the steel is reduced by one-half. This effects a great saving in a structure. Although more concrete is used, the mixture is not so rich, and the amount of metal used is less. The writer has found for 1-3-6 concrete that the economical percentage for the steel to be near 0.75 per cent and this was found to be the same as that used recently in building the stadium at Cambridge, Massachusetts,—probably the largest reinforced concrete building structure so far attempted. The proper percentage for steel to be used is a problem that must be worked out by the individual, and depends upon the relative costs of the component parts which go to make up the beam.

Mr. Condron—In the tests that have been described in Prof. Howe's paper, the maximum percentage of steel is less than 0.70 of one per cent and in over one-half of the beams the per cent was less 0.60 of one per cent. This percentage of reinforcing developed the compression strength of the concrete, and I would like to know if Prof. Hatt can give a reasonable explanation why with two per cent he was unable to develop the compression strength of his concrete, while with 0.60 of one per cent Prof. Howe developed the compression strength of the concrete in 15 out of 18 beams.

Prof. Hatt—I do not know what quality of concrete Prof. Howe used in his tests. The concrete, as I understand it, was made up in cold weather, and when the beams were tested it was not in good condition.

Mr. Condron—On the contrary the beams were made up in ideal weather for concreting—in October—and at a city 200 miles south of here, where the weather is as good for concrete work as you could imagine. At the age of 29 days, when the first two beams were tested, the concrete was still damp inside of these two beams, but was perfectly dry and very hard indeed on the surface. When these two beams were taken out of the machine it was exceedingly difficult to break the concrete, although it had not obtained its full compressive strength. The beams were excessively heavy, weighing from 2,000 to 5,000 pounds each. The means for handling were entirely inadequate for such heavy beams, and the tests had to be postponed until some overhead travelers could be built. In the meantime the beams were kept in a basement at a very uniform temperature, about 65 degrees. When the beams were tested during the Christmas holidays, the concrete was perfectly dry in the interior of these beams, and the difficulty in breaking them up was very great. There were four laborers employed, and it took these men in the neighborhood of three hours to break up one of the beams after it was removed from the machine, working as hard as they could with the means at hand. The concrete, therefore, was not so very poor. The compression blocks which were six inches square by nine inches high were not made with sufficient care to give uniform results for the compression tests. However, they developed a strength of from 1,000 to 2,000 pounds per square inch. Those that were tested at the age of 28 days developed strength varying from 750 to 1,300 pounds only, but at the age of two and one-half months the tests showed considerably more strength and in one case exceeded the capacity of the 100,000 pounds machine. Some of the beams were not broken up after testing and were left in the basement. I now learn that it is almost impossible to cut or break the concrete, it is so hard.

Prof.. A. N. Talbot—I have been very much interested in these two valuable papers, which give information along lines on which information is needed. This is a fruitful topic, and there are yet many phases of it to be investigated. The papers are valuable contributions to our knowledge of reinforced concrete.

There are a few points that it seems to me may well be discussed, and I bring them up more for the purpose of starting a discussion than for giving information myself.

The first is concerning the point from which the factor of safety of the beam should be calculated. Professor Hatt, in his paper, has used the point of first visible crack, saying that this should ordinarily be taken as the point of failure. Mr. Condron and Mr. Johnson refer to the final failure as giving the governing strength, or basis from which the factor of safety should be applied. As I look at it, the point of first visible crack is of comparatively little value. There must be cracks before that time.

In fact the first cracks probably exist when the tensile stress in the lower fiber of the concrete reaches that at which failure in plain concrete occurs, perhaps at one-third the load at which the first visible cracks appear. The Terre Haute tests show, and more recent tests at the University of Illinois agree with this, that there is a marked change in the characteristics of the load-deformation diagram, a crook or elbow, at a point near where calculation shows the tensile stresses in the reinforced beams to be the same as the ultimate tensile stresses of plain concrete beams. The sudden increase in the elongation of the steel beyond this elbow indicates that the steel has been given a part of the tension which before was taken by the concrete.

This point of change of the direction of the load-deformation curve corresponds to what Professor Hatt has called point A of the deflection curve, though the change in the deformation diagram is much more apparent. The amount of the stretch of the steel at this point, and the amount of compression of the upper fiber, is practically the same as the amount of elongation and compression at the breaking point of plain concrete beams of the same size loaded under the same conditions. That is to say, for an elongation of the lower fiber at which the concrete itself would break in tension, there is a marked change in the load-deformation diagram of reinforced concrete beams. There is no change whatever in the diagram at the point where the visible crack appears.

I was much interested in the formulas given. I had hoped that Professor Hatt would explain why he used the parabola. So far as I have been able to observe, the parabola as used is hardly closer to the line than the straight line. The stress area for such conditions becomes four-sevenths instead of two-thirds, and the value of the moment of the compression side is, as I remember it, four-elevenths instead of that given in the other formulas. These values correspond closely with those used by Mr. Johnson.

It seems to me we are just on the eve of a great development in steel-concrete construction, but there are many things yet to be determined, and investigated before we may be sure of proper construction. One is the question of shear. I think Professor Hatt is right in saying that it is a tensile stress that is to be considered—a diagonal tensile stress which is brought into action by the shearing stress. Other matters to be investigated are the effects of repeated loadings and of time loading.

Mr. Condron—I would like to ask Professor Talbot what percentage of steel he used in those beams tested at the University of Illinois, and whether he was able to develop the compressive strength or not?

Prof. Talbot—The percentage of steel we have used varies from about four-tenths per cent to one-half per cent. Very few of our beams have had the failure in compression developed, only in those beams having a large amount of metal. Generally the failure is due to the steel having reached its elastic limit.

The completion of these tests brings out the fact that the full compressive strength of the concrete was developed only when the beam contained more than one and one-half per cent of steel of 33,000 pounds per square inch elastic limit, or more than one per cent of steel of 55,000 pounds per square inch elastic limit. Except in these beams, the maximum load is when the steel has reached its yield point.

Mr. P. C. McArdle—It has been stated that crusher run limestone would make very poor concrete. I wish to state that in this market crusher run does not show more than 8 to 12 per cent of the material passing through a one-half inch mesh. Mr. Howe states that the crushed limestone was in two parts—one coarse and the other fine, and the two mixed formed the run of the crushed stone. The coarse would pass a one and one-half inch mesh and would stop at one-half inch mesh and the fine stone would pass a screen with one-half-inch mesh. I would like to ask whether or not in the work that failed, if the stone itself was crusher run or whether 50 per cent of it was screenings?

Mr. Johnson—The percentage of crusher run in these beams is a little uncertain. I think, in view of the fact that they use part large sizes of rock, the percentage of crusher run is very much more than in the actual crusher run. The trouble was, some of the rock was delivered as it came from the crusher and some was separated, and then they tried to combine it to make an average crusher run. I think as a matter of fact that the percentage was much more. I have had a good deal of experience with the crusher run, but only on one and one-fourth-inch mesh, taking everything that will pass through that size opening. In many cases it is advisable to limit the large material; if you are working with small forms or moulds, there the percentage is a good deal more. The crusher run will be perfectly satisfactory if you are going to use one and one-half-inch material, and what crusher run you find, you find with that, but the general nature of the objection is that you have to provide cement to fill the voids, and that statement also proves consistent with the large number of experiments that have been made by Mr. Noble and others. Where you use the proportion of 1-2-5 you have got the percentage necessary to fill the voids. A limestone screening mortar is stronger than a sand mortar.

Mr. McArdle—As a matter of fact there was probably 40 per cent more screenings than ought to be there for ordinary crusher run for concrete.

Mr. Johnson—The intention was to use a mixture of 1-2-5, but they thought crusher run was generally used, and they used some fine stuff.

Mr. McArdle—I have made tests using screenings as sand in 1-3-6 mixture and torpedo sand in 1-3-6 mixture and found the crushing of the screenings concrete to be nearly 100 per cent better at three months old than the sand concrete.

Mr. B. Williams—It seems to me there is a little confusion in this matter, and that perhaps the surface of the sand, broken stone, etc., to be covered by cement has been confused with the interstices to be filled. The object is always to fill the interstices complete with cement, and if that is done, all the surfaces will be covered. I can see how, if there is too much of fine dust from the crusher, it will take more cement, and may not give as good a result as if there was too little. But if there is a proper amount, reasoning would lead you to conclude that the fine material would be a benefit if properly mixed.

Mr. Johnson—That is a question I would not want to enter into at the present time, and would refer the gentlemen who have any doubts on that subject to a very exhaustive series of tests by Prof. Newberry, published in the proceedings of the Indiana Engineering Society, in which he shows that it is not merely a function of filling the voids.

Mr. L. K. Sherman, M. W. S. E., (by letter)—In the discussion of Prof. Hatt's paper on formulæ for concrete-steel beams, I brought up the point that the modulus of elasticity of concrete was not a constant. I cannot agree with Prof. Hatt that this is an unimportant point.

The report on Tests of Metals and other Materials, made at the Watertown Arsenal, for 1898–9, page 547, has recorded some 500 experiments on the modulus of elasticity of concrete. From this report I present the following average moduli of elasticity of concrete. The concrete was made of mortar, one to two, in the proportion of 40 per cent of the stone. This is practically a 1-2-4 concrete :

Modulus of Elasticity under a load between 100 and 600 pounds per square inch is 2,670,000; under a load of 600 to 1,000 pounds per square inch it is 2,348,000, and for loads of 1000 to 2000 pounds it is 1,597,000.

In none of these 500 experiments, or in the experiments of Bach to which I previously referred, is there an exception to the law that the modulus of elasticity of concrete varies in an inverse ratio to the stress.

The basis of all design for concrete-steel is the proportion $\frac{\text{E steel}}{\text{E concrete}}$. Which figure for E are you going to take — 2,670,000, or 1,597,000? My answer would be, use the former for working stresses of concrete and use the latter if designing for ultimate strength.

REINFORCED CONCRETE.

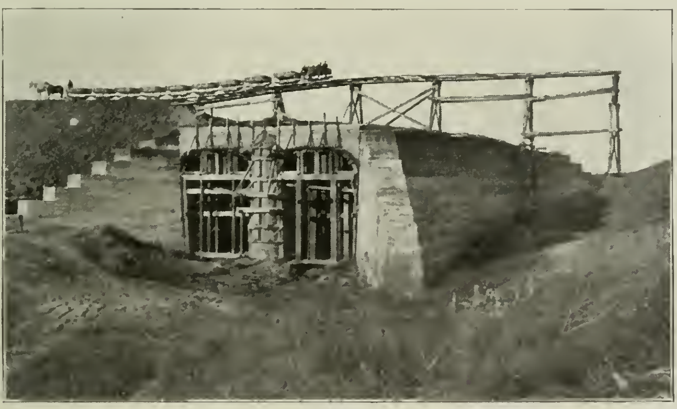
A DISCUSSION.

June 1, 1904.

Mr. C. H. Cartlidge, M. W. S. E.—At the previous meeting of the Society, April 6, at which the subject of steel-concrete construction was discussed, the writer moved the postponement of the discussion to a later date. At the time the motion was made the discussion had drifted into one of the advisability of using "crusher run" stone in such construction. This seemed to be a detail which might be of great importance, and as the hour was so late it was evident that it would be impossible to devote sufficient consideration to the subject.

The writer has no very valuable evidence to lay before the Society bearing upon this matter, but has had some experience with steel and concrete construction, in which crusher run stone was used as well as some in which the concrete was made solely of screened stone in the aggregate.

During the past winter a considerable amount of steel-concrete has been built under his direction, mainly in culverts of from four to twenty feet span, with flat tops, in all of which the stone was crusher run. In no case has there been a failure of any sort in these structures, and it must be said, on the other hand, that nothing like the bending moments for which they were designed, has been brought into play.



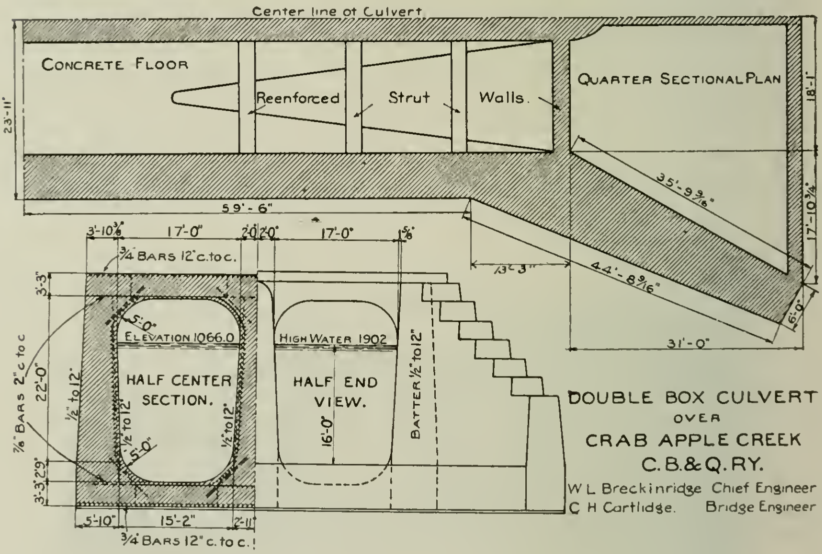
Crab Apple Creek Culvert.

The writer was among the first, he believes, to design a flat top steel-concrete culvert, of large span, with a foundation proportioned to the different pressures along its length. One of these culverts is shown.

This design has been published and as experience has demonstrated that certain features of this design ought to be altered, it is only fair that these should be pointed out, although it is probable that they have been evident to other designers of similar structures.

The most conspicuous defect in the design shown developed after the structure had been partially loaded with the earth fill. At this time a small crack appeared in the lower portion of the two side walls, extending upward nearly vertically about to the beginning of the curved portion. This crack is very fine, not greater than $\frac{1}{32}$-inch. Examination showed the concrete to be very hard, that there had been no rupture of the bond between concrete and steel and that none of the bars, at least near the surface, was broken.

When considering the conditions affecting such a structure, the cause of this crack is evident. There is, of course, no solid foundation. If the load along the top of the culvert were uniform, it would be a simple matter to design it so there would be no possibility of its cracking. As it is, the load is uniform over only a short distance near the middle of its length, and lessens rapidly as the height of the fill decreases. It will be noticed that under the middle portion the bottom is built solidly across, while it is cut away entirely at the ends, leaving at the ends, only the areas of the side walls and the wings for bearing on the foundation. Here is where the difficulty comes in and the cause of cracking in the culvert shown. The wing walls must necessarily be computed as retaining walls, with bases accordingly, and the areas of the bases of these wings is so great, in proportion to the weights they are called upon



DOUBLE BOX CULVERT
OVER
CRAB APPLE CREEK
C. B. & Q. RY.
W L Breckinridge Chief Engineer
C H Cartlidge. Bridge Engineer

to support, that they do not settle uniformly with the body of the culvert, developing a bending moment which is too large to be economically provided for.

It has been suggested that the culvert be built with temporary wings of piling and bulkheads, the culvert allowed to settle, and the wings built subsequently, and the writer believes that this has been successfully tried.

Taken all in all the steel-concrete structures thus far built under the writer's direction are better structures than any he has been able to construct of plain concrete, both from point of cost and durability, and the experience gained is considered a justification of its continued use and of still further application of the system.

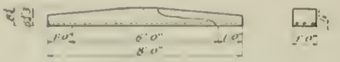
In a comparatively new construction such as this, great care must be exercised, in case of apparent failure, not to condemn it unjustly. It is very easy, in designing with this material, to design improperly and the result is too apt to be laid to the material. There naturally exists a prejudice against any new material, or a new form of construction, until it has been tried in the furnace of experience. It rests with the engineers who use it to be careful that any failures shall not be due to illy-considered design.

Mr. Jas. J. Harding, M. W. S. E.—In preparing a written discussion on the subject of reinforced concrete, it was thought that it might be of some interest to the Society to make a report on a series of tests made by the Bridge and Building Department of the C., M. & St. P. Ry. during the latter part of 1902.

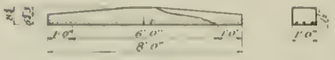
This company commencing, in the early part of that year, the use of reinforced concrete in the covers of box culverts and finding but little information on the subject outside of trade catalogues, decided that a number of beams should be made and broken to determine whether or not they would develop in bending, the strength accredited to them by the formulæ used in the design. It was not the intention that these tests should cover any ground except to obtain as closely as possible the ultimate strength that beams, as actually built and used in the covers of box culverts, would develop in bending. No attempt was made to determine the location of the neutral axis and the method used for measuring the deflection could give only approximate results.

The metal reinforcement consisted of longitudinal bars placed along the bottom of the beams, no provision whatever being made to reinforce the beams in shear; in fact, the writer is obliged to admit that the liability of the beams failing by shear did not occur to him at the time the beams were designed.

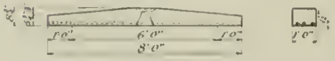
The results of these tests are presented to the Society with the knowledge that they are perhaps somewhat crude and are not as complete as they would have been made with our present knowledge,



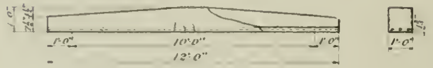
Beam 1



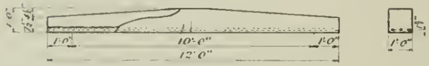
Beam 1a



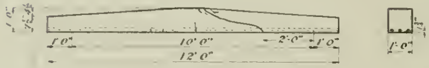
Beam 1b



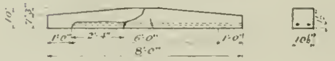
Beam 2



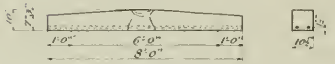
Beam 2a



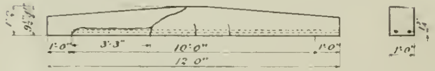
Beam 2b



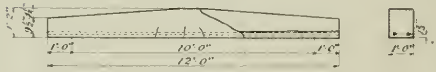
Beam 4



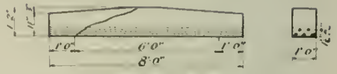
Beam 4a



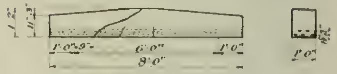
Beam 5



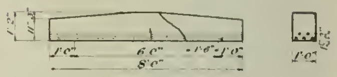
Beam 5a



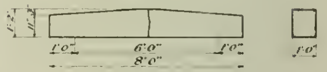
Beam 3



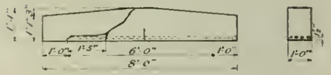
Beam 3a



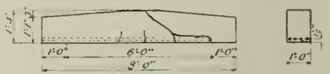
Beam 3b



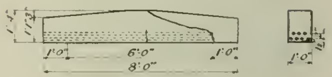
Beam 3c



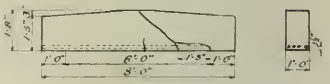
Beam 6



Beam 6a



Beam 6b



Beam 6c

Beam	Clear Span	Age	% of Steel to Concrete	Bars.		Wt of Beam bet. Supports	External load at first Crack	In lbs Developed at first Crack	Comparison with Theory	External load at Ult. Failure	In lbs Developed at Ult. Failure	Comparison with Theory
1	6' 0"	7 Days	.62	Corrugated Bars	3-½"	570				12300	220000	1.31
1a	"	28 "	.62		3-½"	570	12000	221100	1.26	15700	287600	1.61
1b	"	99 "	.62		3-½"	570	8000	198100	1.14	18700	341200	1.95
2	10' 0"	7 "	.88		3-¾"	1300				13750	432000	.88
2a	"	28 "	.88		3-¾"	1300	12000	379500	.77	17600	517500	1.11
2b	"	99 "	.88		3-¾"	1300	9800	313500	.64	28800	886500	1.79
3	6' 0"	7 "	.62		5-½"	985				26600	486900	1.02
3a	"	28 "	.62		5-½"	985	17500	323000	.68	30700	561400	1.13
3b	"	89 "	.62		5-½"	985	27500	503900	1.05	45000	818900	1.71
3c	"	25 "	No Steel			975				6800		
4	"	29 "	.56	Twisted Bars	2-½"	600	6000	113400	.59	21500	391100	2.03
4a	"	125 "	.56		2-½"	600	7000	131100	.68	17000	311100	1.61
5	10' 0"	29 "	.71		2-¾"	1500	10000	322500	.61	32500	997500	1.89
5a	"	125 "	.71		2-¾"	1500	12000	382500	.72	35000	1072500	2.02
6	6' 0"	33 "	.57		4-½"	1150	17500	325300	.52	37500	685100	1.09
6a	"	125 "	.57		4-½"	1150	27000	496400	.79	48000	874100	1.39
6b	"	31 "	1.06		7-½"	1160	25000	460500	.62	45000	820500	1.09
6c	"	33 "	.45		4-½"	1450	35000	643100	.91	55000	1003100	1.47

but with the hope that they may be of some aid in the discussion of this very important subject.

Eighteen beams in all were made with the percentages of steel to concrete varying from 0.45 per cent to 1.06 per cent, and one beam having no steel reinforcement whatever.

The concrete was what we call our "first-class mixture," similar to that used by the department in the covers of box culverts, and was made up of one part Portland cement (Atlas brand), two parts of clean fine sand, and five parts of broken limestone under two inches. The beams were made at our West Milwaukee shops where a concrete crew was then at work putting in building foundations. The foreman was furnished with a plan showing the general dimensions, and the rods were shipped to him from our stock supply. No especial supervision was made over the work; and no instructions were given him in the actual construction work. As a result of this lack of supervision an error was made in the construction of a part of the beams. The bars furnished for beams 4, 5, 6, 6-a, 6-b, and 6-c were about 12 inches short, and were placed by the foreman as indicated on the diagram, that is, all of the shortage was at one end of the beams, bringing the ends of the bars at about the the point of support. The result of this error shows up in the failure of the beams.

Corrugated bars were used in the reinforcement of beams 1 to 3-b, inclusive; beam 3-c, which had the same general dimensions as 3, 3-a and 3-b, had no steel reinforcement whatever. Beams 4 to 6-c inclusive were reinforced with twisted bars. No compression tests were made of the concrete and no tests were made to determine the ultimate strength and elastic limit of the bars used in these beams, but a number of other tests made about the same time on bars taken from our stock supply, showed an ultimate strength varying from 80,000 pounds to 92,000 pounds per square inch for the corrugated bars, and an average elastic limit of about 60,000 pounds per square inch.

The twisted bars developed about the same strength, with the exception of one half-inch bar, which developed an ultimate strength of only 65,000 pounds per square inch. This bar, however, had considerably fewer twists than the other bars, which probably accounts for its lower value.

The accompanying diagram clearly indicates the general dimensions of the beams and of the size and kind of reinforcement. The slope given to the top of beams corresponds to the water shed used in actual construction.

The load in all cases was applied at the center with a 200,000 pound Olsen testing machine.

Beam 1, 7 days old. First crack not recorded. Failed in direction shown at 12,300 pounds. Fracture 2 inches from support, and concrete not thoroughly dry. Maximum deflection, $\frac{5}{16}$-inch.

Beam 1-a, 28 days old. First crack at center at 12,000 pounds. Failed in direction shown at 15,700 pounds. Maximum deflection, $\frac{21}{32}$-inch.

Beam 1-b, 99 days old. Small cracks which appeared at about 8,000 pounds were four inches from center, and afterward opened up as weight was applied. Beam failed by crushing at top. Ultimate failure 18,700 pounds. Maximum deflection ⅞-inch.

Beam 2, 7 days old. First crack not recorded. Failed by opening up from loading point in direction of support, fracture about 14 inches long. When forced down the beam broke along the upper line of bars. Ultimate load 13,750 pounds. Concrete not thoroughly dry. Maximum deflection, ⅝-inch.

Beam 2-a, 28 days old. First cracks at 9,800 pounds were ¾-inch and 2¼-inches from center. Failure similar to 2 and 2-a. Did not force beam down. Ultimate load 28,900 pounds. Maximum deflection, 1 inch.

Beam 3, 7 days old. First crack not recorded. Failed in direction shown from load to support at 26,600 pounds. Maximum deflection, $\frac{9}{32}$-inch.

Beam 3-a, 28 days old. First crack at 17,000 pounds. Failed in direction shown from load to a point 9 inches from support at 30,700 pounds. Maximum deflection, ⅜-inch.

Beam 3-b, 89 days old. First crack at about 27,500 pounds was 2½ inches from center. Commenced to open up from load at an angle of about 45 degrees at 45,000 pounds. Maximum deflection, ¼-inch. Recovered after first crack to about $\frac{1}{64}$-inch.

Beam 3c, 25 days old. Same dimensions as 3, 3-a and 3-b with no steel reinforcement. Broke at center under 6,800 pounds external load. Dividing bending moment by section modulus gives a stress of 335 pounds per square inch in the extreme fibre.

Beam 4, 12 days old. First crack near the center at 6,000 pounds. At 8,000 pounds a crack appeared at 8 inches from center, and the final failure at 21,500 pounds extended from this crack up to about the center of the beam at top. When forced down, the beam crushed at top and finally sheared along the top of the bars to the support at and where the bars were short. Maximum deflection, ⅝-inch.

Beam 4-a, 125 days old. First crack near center at 7,000 pounds. Other cracks appeared later near the center and afterward opening up and the final failing was by crushing on top at 17,000 pounds. The top surface of this beam at the center was very rough and pitted with the edges broken off. The low ultimate strength, which was lower at 125 days, than beam 4 of the same design at 29 days, was probably due to poor construction. Maximum deflection, $\frac{7}{16}$-inch.

This was the only beam in which the ultimate strength did not increase with age.

Beam 5, 29 days old. First crack near center at 10,000 pounds. At 21,500 pounds a crack appeared at a point 21 inches from center which opened up toward the load and the beam failed at 32,500 pounds. When forced down the beam sheared along the bars toward the end of the beam where the bars were short. Maximum deflection, $\frac{13}{16}$-inch.

Beam 5-a, 125 days old. First crack appeared at 12,000 pounds near the center. At 35,000 pounds the face of the beam opened up near the center. The fracture extended from loading point at about 45 degrees. When forced down the beam broke along the line of the bars which were of full length. Maximum deflection, ¾-inch.

Beam 6, 33 days old. Small crack near the center occurred at 17,500 pounds. A crack 19 inches from the center, appeared at 25,000 pounds, and afterward opened up toward the load at 37,500 pounds. When forced down the beam broke along the line of the bars toward the end where the bars were short. Maximum deflection, ¼-inch.

Beam 6-a, 125 days old. Crack near the center at 27,000 pounds. Failure similar to beam 5-a at 48,000 pounds. When forced down the beam broke along the bars toward the end where the bars were short. Maximum deflection, $\frac{3}{16}$-inch.

Beam 6-b, 31 days old. First crack at 4 inches from the center and at 25,000 pounds. Failed from loading point toward the support at 45,000 pouuds. Maximum deflection, $\frac{3}{16}$-inch.

Beam 6-c, 33 days old. First crack at 2 inches from center with load of 35,000 pounds, followed by a crack 16 inches from center. At 55,000 pounds a fracture appeared on the face of the beam extending from the load to the latter crack. When forced down the beam broke along the line of the bars toward the end where the bars were short. Maximum deflection, ¼-inch,

The result of these tests are tabulated in the table. Column 8 gives the total inch pounds developed at first crack, and column 11 gives the inch pounds developed at the ultimate failure of the beams. Column 12 gives a comparison of the ultimate strength as developed by the tests and that obtained from the formulæ. A straight line formula was used as a basis for the theoretical comparison, giving to the steel a constant value of 30,000,000 pounds per square inch for the modulus of elasticity (E), and 50,000 pounds per square inch for the elastic limit. No value was given to the concrete in tension.

To obtain a formula, which would give the per cent of steel to concrete used in each particular case, the ratio of the modulus of elasticity (E) of the concrete in compression to the elastic limit of the concrete in compression was varied, and on the formulæ thus obtained the comparison was based.

Column 9 gives a comparison between the strength developed by the tests at the first crack noticed and the ultimate strength obtained from the formula.

The writer does not wish to go on record as saying that the first crack noticed was the first actual crack. At three of the tests two men, and at two of the tests three men kept a close watch for the first crack, but it is possible that they appeared in some of the beams at a smaller load than indicated in the table, and were not noticed, but omitting beams 1-a, 1-b, 3-b and 6-c, which seemed to give very high values, and taking an average of the others, we find that the first noticeable crack appeared at 0.66 of the theoretical ultimate strength. This point, which might well be called the elastic limit of the beam, seems to bear about the same relation to the ultimate theoretical strength of the beam, as the elastic limit of steel does to its ultimate strength. On all of the beams excepting 1 and 2 the load at first crack increased materially with the age of the beam. On beams 1 and 2 the reverse was true, but as before stated, the cracks might have appeared sooner and were not noticed.

For ultimate strength all of the beams except No. 4 showed a marked increase with age. This beam No. 4 was the one noted as being poorly constructed, failing by crushing under the loading point.

The result of tests on beams reinforced with twisted bars seemed to give very erratic results for ultimate strength, beam 4 at 29 days, developing more than twice the theoretical requirements, while beam 6 with the same percentage of steel to concrete and four days older, but little more than developed the theoretical strength. The shortage of bars may have had some bearing on this result, although the same defect occurs in both beams.

Taking an average of the results of beams broken at 89, 99 and 125 days, we have an ultimate strength averaging 1.76 times the theoretical requirements for bending moment.

The failure of all the beams reinforced with corrugated bars was similar, with the exception of beam 1-b which was clearly a compression failure. On the other beams the first sign of failure, neglecting the bending moment cracks, was in every case an opening up on the face of the beam, generally at about the one-third point, and extending at an angle of about 45 degrees with the horizontal. This fracture was followed immediately by the drop of the scale beam, which meant the ultimate strength for continued pressure. The lines of failure indicated on the plan are the fractures where tests were carried to destruction. This same method of failure was characteristic of the beams reinforced with twisted bars, except beam 4-a, which failed in a similar manner to 1-b, the concrete crushing on top at the center.

There seems to be no question as to the cause of the failure in any of these beams.

Beams 1-b and 4-a were clearly bending moment failures, the ultimate strength of the concrete in compression being developed in both cases.

In beams 4, 5, 6 and 6-c the final fracture started at a bending moment crack and failed toward the loading point. The failure being due to a tensile stress which was the resultant of the horizontal and vertical shears. It is possible that the failure of beams 3-b, 5-a and 6-a also started with bending cracks, but the records of the tests do not indicate whether the crack shown as extending from the bottom of the beam up to the line of failure appeared before or after the ultimate fracture.

The failure of all the beams reinforced with corrugated bars, with the exception of 1-b and possibly 3-b, as before stated, was an opening up on the face of the beam, due to a tensile stress caused by the resultant of the horizontal and vertical shear. All of the older beams failed at about the ultimate strength of the steel. Take for example beams 2-b and 3-b, both of which developed about the average ultimate strength, and let us determine what stress there was in the steel at the ultimate failure. Taking the bending moment given in the table and dividing it by the area of the steel multiplied by the lever arm (which is the distance between the center of gravity of the steel and the center of gravity of the compression area), we find that the bars in beam 2-b were stressed to about 90,000 pounds per square inch, and in beam 3-h were stressed to about 86,000 pounds per square inch. From this it is seen that the elastic limit of the steel was passed, and the ultimate strength almost reached at the time of failure. Under these conditions there must have been an enormous stress in the concrete above and around the steel, and the ultimate compressive strength of the concrete not having been developed, it is easily seen why the beams should have failed in the way that they did. The writer believes that had the beams been made with the same depth at the ends as at the center, and broken at an age of from two to three months and by loading uniformly, or at four points instead of at the center, the full theoretical strength of the beams would have been easily developed, and this without the aid of shear bars, though admitting at the same time that the presence of shear bars would have undoubtedly increased the strength.

To determine whether the above assumptions are correct, and to further determine if possible the relative value of shear bars, the bridge department decided that further tests should be made. To this end we are now having made some 28 beams with spans 8, 12, 15 and 18 feet in the clear, and for varying loads. These will be reinforced with corrugated, twisted, and trussed bars, with and without shear bars. The percentage of steel to the concrete above the steel will be 0.65 in all cases, this being the value decided on as the most economical, all things considered.

These beams will be broken in a few months, and it is hoped will throw some additional light on the question of shear and the relative value of shear bars. For the present the writer makes it a practice to use shear bars in single beams where the ultimate shear exceeds 140 pounds per square inch. For slabs such as the covers of box culverts the value is increased to 160 pounds. With a factor of 4 this would give a safe value of from 35 pounds to 40 pounds per square inch.

During the discussion of the papers presented by Professors Hatt and Howe at a former meeting the question arose as to whether the factor of safety of a reinforced beam should be based on the first crack or on the ultimate strength. In designing culvert tops the writer used a factor of 5 for live load and 3 for dead load, based on the formula for ultimate strength. If the first crack appears at about 0.66 of the theoretical ultimate load as these tests indicated, we would then have a factor for the first crack of about 3¼ where the cover is close to the rail, and a factor of about 2 where the load is all dead. This compares closely to the factor used in steel construction and based on the elastic limit of steel.

Where plain bars are used with no mechanical bond and not anchored there can be no question but that the factor of safety should be based on the first crack, inasmuch as thereafter there is nothing to depend upon, except the adhesion of the concrete to the plain bar, upon which little reliance can be placed. In addition the ultimate failure of such a beam follows quickly after the first crack.

Mr. J. A. Fulton, M. W. S. E.—This small sized model of a rectangular beam, which is illustrated in Fig. 1, consists of strips of cardboard glued together for a distance of about one and one half inches at the center but left entirely free at the ends.

It is extremely flexible in a direction at right angles with the plane of the layers; but is quite rigid in the other direction with the layers on edge.

When held in its weak direction and loaded, the layers slip past each other at the ends, and the end surface of the beam becomes a series of steps and is no longer at right angles with the axis of the beam; and it may be of interest to note that the depth of the beam is neither increased nor diminished by this slipping and that the slipping is about the same in amount between each succeeding pair of layers.

The extreme weakness of this beam when the layers are placed flatwise is due to this slipping of the fibers, or in other words it is due to the lack of ability to resist longitudinal shear; and since this slipping appears to be about the same at all heights it seems fair to assume that the horizontal shear is substantially the same at any height between the top and bottom of the beam.

Referring to Fig. 2: If the longitudinal shear stress developed between any two points A and B is greater than the shearing strength of the horizontal section AB then special provision should be made for additional horizontal shearing strength between those points.

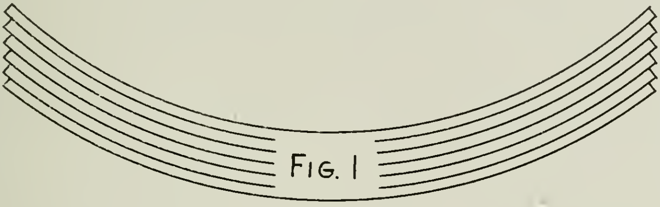


Fig. 1

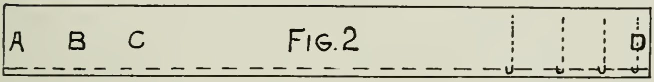


Fig. 2

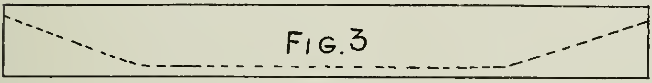


Fig. 3

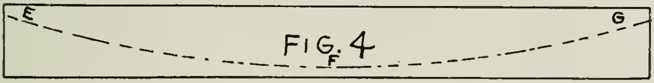


Fig. 4

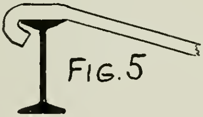


Fig. 5

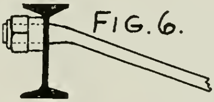


Fig. 6.

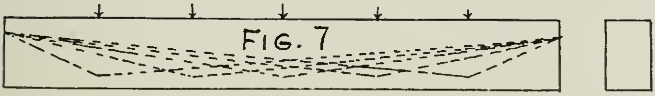


Fig. 7

Horizontal rods as indicated by the dotted lines in this figure, either plain or upset, do not seem to make such provision.

It has been suggested that vertical stirrups hooked under the re-enforcing rods as at D will strengthen the beam. Doubtless this claim is true to some extent but for a wholly different reason from what was at first supposed.

There appears to be no reason why these stirrups should lengthen under a load distributed over this beam, hence there is no tension on them. Similarly it is not evident that they should shorten under such load, therefore there is no compression on them. Apparently the only force applied to them is a cross shearing force at right angles to their length, and limited not by their own cross-sectional area but by some obscure and indeterminate amount of bearing area against, and tending to crush, the concrete.

If the re-enforcing rods are turned up as in Fig. 3 or Fig. 4 and properly secured, we thereby effect a radical change in the design and make provision for the horizontal shearing stresses.

For a uniformly distributed load the re-inforcement shown in Fig. 4 seems the better. This re-enforcement hangs as a suspended cable. The horizontal component of the stress in this cable is the same at E as at F. The actual stress at E is but little greater than at F.

The increment of stress between E and F is therefore small in amount and relatively insignificant; and since little or no stress is actually applied between F and E it is useless to provide means for taking up the stress between those points; and it seems as if we must conclude that the proper place for the concrete to take hold of these re-enforcing rods is at their ends and not at intermediate points, and that a plain rod will do substantially the same work as an upset or a twisted one, and that any kind of a rod will fail, or is likely to fail, unless provision is made to develop the full strength of the rod at its ends, and that with such provision it becomes a matter of comparative indifference whether adhesive contact is maintained or not.

It seems reasonable to assume, however, that the concrete may be expected to perform two offices, the one being to resist the pull of the cable as a direct thrust, and the other being to act as a stiffening girder for the cable which otherwise might be flexible; and in the performance of this latter office it is clearly desirable that adhesion of some kind should be maintained, although it seems to be of minor importance.

If the rods are to be hooked over the flanges of I-beams, as in Fig. 5, we are confronted with the fact that the thin edge of an I-beam flange does not present a very good bearing surface for a large rod.

If the full strength of the rod is developed the beam edge will be overloaded; and in any case such a hook is not a well-designed tension member; and moreover it would scarcely be possible with even the softest steel to make so sharp a cold bend, and altogether impossible with high steel.

A better device would be an upset screw-ended rod, as in Fig. 6, with nut, and provided with a thick washer so that there shall be no screw threads bearing downward against the web of the I-beam.

The suspended cable as just described seems all right for a constant uniformly distributed load, but is to some extent flexible under a concentrated or a moving load.

The device shown in Fig. 7 is suggested as a rigid girder under a moving load.

Bridge men will recognize this as the shade of the old Bollmann truss, it being assumed that the concrete will be able to do duty as vertical posts at the panel points and as the top chord of the truss.

The stresses in such a structure might be to some extent ambiguous, but the enclosing mass of concrete would tend to neutralize its various eccentricities.

It would seem as if such a beam might have some merits of its own, but actual tests in full-sized specimens might be necessary to determine whether it has not also some defects of its own too serious to be overlooked.

There seem to be some differences of opinion in regard to the qualities that should be sought in the concrete and in the reinforcing steel, and in the relative cross sections of the two.

If we are going to use concrete in a way that will be dependent on its crushing strength it would seem as if we should make it without any voids, requiring ordinarily 1-2-4 mixture, mixed wet.

Its tensile strength under even the most favorable circumstances is relatively so insignificant that whenever we are intending to use a steel reinforcement we might as well ignore altogether the value of the concrete in tension.

Good concrete ought to have an ultimate compressive strength of say 2200 pounds per square inch. If we use steel having an ultimate tensile strength of say 55,000 pounds per square inch, we insert in the tension flange a material having twenty-five times the unit strength of the material we are going to use in the compression flange; and we say therefore, that the steel tension area should be one twenty-fifth or four per cent of the concrete compression area; and since the compression area is not far from one-half of the whole area we shall be substantially correct if we make the steel area two per cent of the entire beam area.

But we shall need further tests before the present methods of concrete reinforcement can be adopted as standard and accepted practice.

Mr. F. H Bainbridge, M. W. S. E.—The reading of Profs. Howe's and Hatt's papers marks an important period in the growth of reinforced concrete construction. Both plain and reinforced concrete have been built in the United States as road-bed structures almost entirely by western railways. The exceptions being two eastern railways whose engineering departments are almost entirely composed of western men. The great interest occasioned by the reading of these papers points to the fact that reinforced concrete will

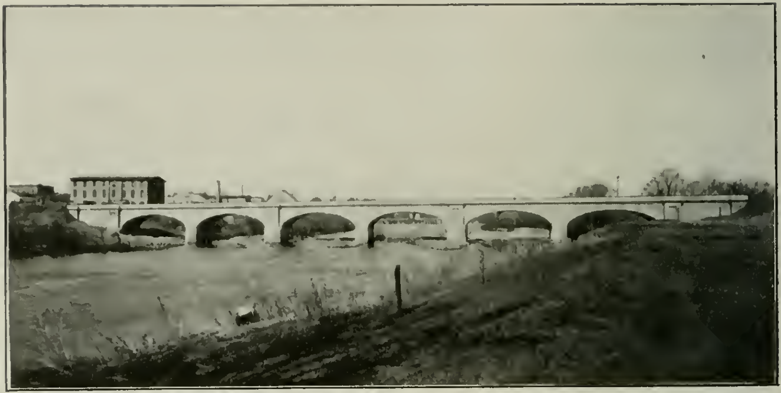


Fig. 1.

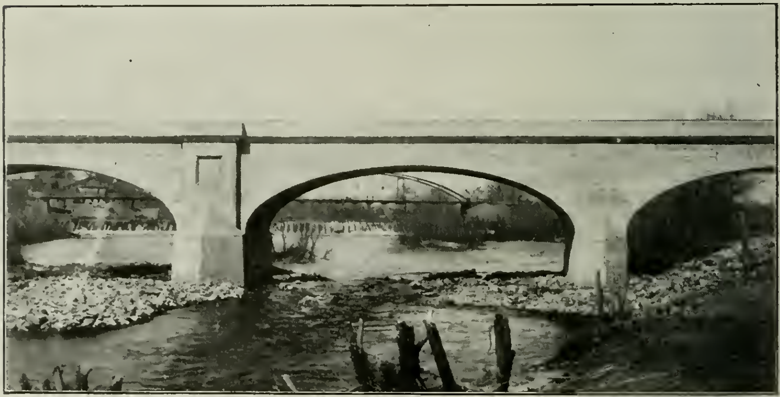


Fig. 2.

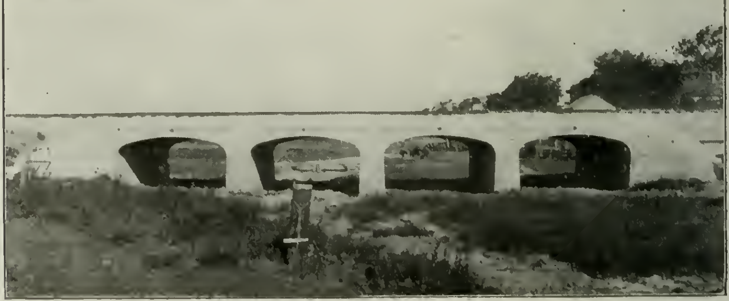


Fig. 3.

in the future largely take the place of metal superstructures, and wooden trestles.

The writer has selected two examples in one of which a King Post Bridge on wooden crib piers has been replaced by a series of concrete arches, which replaced an 85-foot lattice span.

Fig. 1 is a full length photograph of a concrete viaduct over the Cedar River at Nashua, Iowa, I. C. R. R., completed in 1902. The arches are 48-foot clear span, the only reinforcement being between the main arches and the spandrel walls.

Fig. 2 is a detail photograph of the same structure. It will be noticed from the illustration that each alternate pier is built heavy enough to take the full thrust of an arch without the assistance of an adjoining arch, so that if one of the piers is undermined, or carried away, the structure as a whole cannot fail. The entire cost of this structure was $67 per lineal foot, exclusive of track, ballast and filling.

Fig. 3 is a photograph of a concrete viaduct consisting of four 15-foot clear span elliptical arches, which replaced a single track lattice of 85-foot span. This structure carries two tracks. It is reinforced with second hand "I" beams, 10 inches deep. The entire cost, exclusive of track and filling, including the removal of the old structure was $45.38 per lineal foot of single track. Both of the above structures were designed by and built under the superintendence of Mr. H. W. Parkhurst, President of this Society. The architectural beauty of both these structures is remarkable.

A number of other structures similar in design to the photograph (Fig. 3) have been constructed on the Illinois Central Railway with spans varying from 13½ to 15 feet. The average cost of six them being $21.23 per lineal foot of single track, all of them being double track structures.

The writer has been interested in comparing results derived from the formulæ of Mr. A. L. Johnson and Prof. Hatts, and he finds that the two formulæ are substantially identical except that the formulæ of Prof. Hatt are much more general, and allow for varying percentages of steel, as well as taking into account the behavior of a beam from the beginning of flexure until its destruction, assumed to occur at the elastic limit of the steel.

Fig. 4 is a diagram made up after a method originated by Mr. J. W. Schaub, member of this Society, showing graphically the Hatt equations at the elastic limit of the steel and at the point A. The lines O X and O^1 X^1 are figured from constants used in the tests by Prof. Lanza. The lines O Y and O^1 Y^1 are figured from the constants derived from the Howe tests. The table is revised from the data given in the Howe tests, comparison being made with the Hatt formulæ. The agreement of the theoretical results, both in the Johnson formulæ and with the actual ultimate strength of the beam

TABLE GIVING SUMMARY OF HOWE'S EXPERIMENTS, AND COMPARED WITH HATT'S FORMULÆ.

No. Beam.	Age in Days.	Span C to C End Supports.		Number and Size of Steel Bars.		Actual Net Areas of Steel.	Per Ct. of Steel Re-inforce-ment. p	Dist. Center Steel below top of Beam. u	Dist. between Loadi'g Points.		Depth of Beam. h	Breadth of Beam. b	Length of Beam Over All.		Total Weight of Beam.	Total Maximum Load.	Load when Comp. Failure was Marked. Load falling off from Max.	Maximum Moment.	By Hatt's Formulæ. Theoretical Moment at Elastic Limit of Steel.
		Ft.	In.		In.	Sq. In.			Ft.	In.	In.	In.	Ft.	In.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	74	10	0	2	½	0.36	0.60	.85	3	4	5	12	12	0	825	4,200	3,400	94,300	82,600
2	76	12	0	3	½	0.54	0.64	.89	4	0	7	12	14	0	1,150	8,100	5,100	212,200	181,200
3	72	15	0	4	½	0.72	5.63	.89	5	0	9½	12	17	0	2,000	12,100	....	402,700	333,700
4	73	15	0	6	½	1.08	0.64	.91	0		14	12	17	0	2,860	19,400	....	929,800	740,800
5	71	12	0	2	¾	0.60	0.50	.87	1	0	10	12	14	0	1,700	11,900	....	311,900	287,000
6a	71	15	0	3	¾	0.90	0.52	.93	5	0	14½	12	17	0	2,935	18,300	....	607,200	645,000
6b	69	15	0	3	¾	0.90	0.52	.93	5	0	14½	12	17	0	2,950	19,325	16,500	638,300	645,000
6c	115	15	0	3	¾	0.90	0.52	.93	5	0	14½	12	17	0	2,450	20,400	19,100	666,300	645,000
6d	29	15	0	3	¾	0.90	0.52	.93	3	0	14½	12	17	0	2,960	15,500	....	616,800	645,000
6e	29	15	0	3	¾	0.90	0.52	.93	3	0	14½	12	17	0	3,125	17,000	....	692,000	645,000
7a	78	18	0	4	¾	1.20	0.53	.91	6	0	19	12	19	6	4,450	30,000	28,500	1,189,400	1,170,000
7b	78	18	0	4	¾	1.20	0.53	.91	6	0	19	12	19	6	4,325	29,000	23,600	1,152,000	1,170,000
7c	70	17	9	4	¾	1.20	0.53	.91	6	0	19	12	19	6	3,800	30,100	....	1,142,900	1,170,000
7d	68	18	0	4	¾	1.20	0.53	.91	8	0	19	12	19	6	4,450	29,900	....	1,006,400	1,170,000
7e	77	17	6	4	¾	1.20	0.53	.91	3	0	19	12	19	6	4,200	22,800	....	1,090,700	1,170,000
8	77	15	0	2	⅞	1.06	0.63	.91	5	0	14	12	17	0	2,900	23,300	22,300	756,500	741,000
9	77	18	0	3	⅞	1.59	0.63	.91	6	0	21	12	19	6	4,850	34,800	....	1,373,700	1,667,000
10	75	18	0	2	1	1.40	0.65	.90	6	0	18	12	19	6	4,225	29,000	25,700	1,149,300	1,225,000

Beam No. 4. 14,000 applied 6 ft. 6 in. Removed and loaded in center. Failed at load.
Beam No. 6d. Failed by compression near center.
Beam No. 6e. Failed by compression near center. Made of gravel from pit.
Beam No. 7d. Several repetitions of load. Failed by shearing.
Beam No. 7e. Repeated loads. Failed by shearing.
Beam No. 9. Failed by shearing.

as recorded in the Howe tests is seen to be very close. A similar table for the Lanza experiments was compiled by the writer, but the results of these experiments were so erratic that the comparison was of little value.

In the tests made by Profs. Howe and Hatts no account is taken of the initial stress in the concrete beams due to the contraction of concrete in setting.

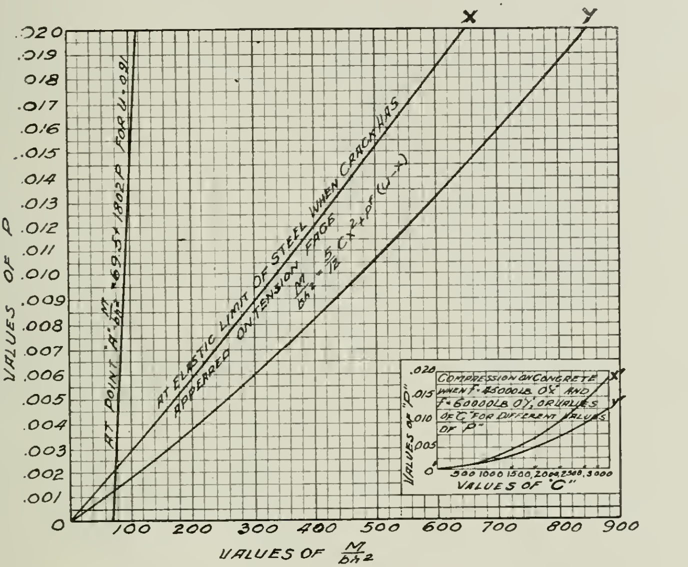


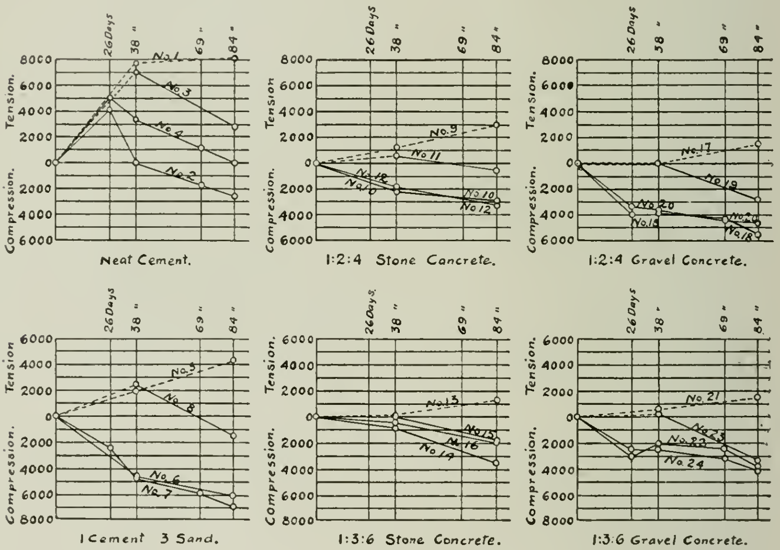
DIAGRAM FOR OBTAINING PERCENTAGE OF STEEL AND MOMENT OF RESISTANCE OF CONCRETE STEEL BEAMS

LINES OX & O'X' FOR LANZA TESTS – $u = .85$ $\frac{E_S}{E_C} = 8.2$ $f = 45000$
" OY & O'Y' " HOWE " $u = .91$ $\frac{E_S}{E_C} = 7.5$ $f = 60000$

Fig. 4.

Fig. 5 shows the result of some experiments made by Sam. W. Emerson and Geo. A. Peabody, students at the Case School of Applied Science, as described in the Engineering News, March 10, 1904. Steel bars were imbedded in concrete blocks 8 x 8 in. x 8 ft. long, and measurements taken over a period of nearly three months. A number of specimens were allowed to set in water, others in water and again removed to air, others set entirely in air. The results obtained are very uniform. All the bars imbedded in concrete which set in water expanded, and all the bars imbedded in concrete which set in air contracted. The extreme contraction occurred on bar No. 7, showing 7,000 pounds per square inch compression, or a contraction in the concrete of one part in 4100. Assuming a modulus of elasticity in concrete of 4,500,000 and a tensile strength of 300 pounds per square inch, a contraction of one part in 15,000 would rupture the concrete if the contraction was resisted. From the results of these experiments it is evident that concrete which sets in air should be generally reinforced to prevent contraction cracks, and also that precaution should be taken to prevent contraction as far as possible by sprinkling the concrete for some time after its construction.

In a concrete beam allowed to set in air, reinforced on the tension side, there will be a compression stress in the reinforcement and a corresponding tension stress throughout the cross-section area of the beam, this being greatest on the reinforced side of the beam, so that before the beam is subjected to flexure there will be a hypothetical neutral axis above the surface of the beam. As soon as the beam is subject to flexure this neutral axis will begin to fall, the compression of the reinforcement will be at once reduced, and no change, or at least a comparatively trifling change, will take place in the stress on the concrete of the under side of the beam, as the reduction of the compression stress in the reinforcement will relieve the tension stress in the concrete due to the compression of the reinforcement.



Neat Cement. 1:2:4 Stone Concrete. 1:2:4 Gravel Concrete.

1 Cement 3 Sand. 1:3:6 Stone Concrete. 1:3:6 Gravel Concrete.

DIAGRAMS SHOWING INITIAL STRESS OF STEEL RODS EMBEDDED IN CONCRETE.

Changes which took place in air are shown by full lines, those which took place in water are shown by dotted lines.

Fig. 5.

Experiments by Prof. Von Schule of Zurich, Switzerland, to be described in this discussion by Mr. Mensch, show that there is little or no contraction in the compression fibres of a beam up to a stress of about 50 pounds per square inch. Both of the above considerations account for the fact that a reinforced concrete beam in flexure can be subjected to a considerable stress without any deflection being noted. This fact has been observed in numerous tests on floor slabs, but it has not been generally accredited by engineers, but it is, however, a fact.

The question of Portland cement concrete laid in freezing weather is an important one, and it would be interesting if the members of the Society would add their experience in this direction to this discussion.

The following is the result of tests made in a laboratory of the Illinois Central Railway. The results given are the average of ten specimens from each kind of test. The briquettes were made from AA Portland cement and standard crushed quartz. Half of the briquettes were allowed to remain in water in the laboratory at a temperature of about + 75 deg. Fhr. The other half were mixed and exposed at a temperature of + 4 deg. Fhr., the exposure being made as soon as the cement mortar was placed in the molds. The temperature of the mixing water was + 70 deg. Fhr. Tests were made on briquettes of 1-2, and 1-3 mortar. The results showed for the 1-2 briquettes at the end of 28 days a strength of 226 pounds per square inch for the frozen specimen,and of 490 pounds per square inch for the water specimen,or that the frozen specimen had 46 per cent of strength of the other. After two months the relative strength was 357 pounds and 539 pounds per square inch, a ratio of 66 per cent. After three months the strength was 496 pounds, and 500 pounds per square inch, or 99 per cent. Of the 1-3 briquettes, at the end of 28 days the strength was 119 pounds for the frozen specimen, and 276 pounds for the water specimen, or the former was 43 per cent of the latter in strength. At the end of two months it was 235 pounds for the former and 326 for the latter, or a ratio of 72 per cent. At the end of three months the results were 329 pounds for the former and 291 pounds for the latter, or a ratio of 113 per cent, showing an actual increase in strength of 13 per cent for the frozen specimen.

It should be remarked however, that in these tests the exact proportion of water necessary to furnish the water of crystalization for the cement, was used and that a considerable excess of water in the frozen specimens would be liable to rupture it. In the writer's experience it is entirely safe to lay Portland cement concrete in any weather, the only danger arising when concrete which has set for three or four hours at a temperature above freezing, is subjected to a rapidly falling temperature below freezing.

Mr. L. J. Mensch—I wish to present some very interesting tests on reinforced concrete beams, made by Prof. Schule in Zurich, which demonstrate that all theories of concrete steel beams based on the theorems of plane surfaces, or the direct proportionality of stresses to extensions and compressions, and a straight line as a neutral axis, cannot be a satisfactory solution of the problem.

The tests were made on six beams 8 inches wide by 12 inches deep, two and half years old. Three beams were of plain concrete, and three beams were reinforced by four ⅝-inch iron rods in both top and bottom. Half of the number were straight and half bent, and connected by hoop irons. The concrete was mixed in the proportion of one part cement to five parts of sand and gravel. The total length of the beam was 5 feet 4 inches, while the span was exactly 5 feet. The tests were made in an Amsler testing machine, the bearings for the beams consisting of 2-inch steel rolls, while a concentrated load was applied in the center.

The plain concrete beams showed the following ultimate breaking loads:

Beam No. 1..................4,180 pounds.
Beam No. 2..................5,390 pounds.

Corresponding to an ultimate compressive and tensile strength of the extreme fibers of 310 pounds and 450 pounds per square inch, if figured by the formula: Bending Moment equals Stress, times Moment of Resistance; this formula is however, not correct for concrete beams on account of the difference of the moduli of elasticity for tension and compression.

On one of these beams was measured the extension and compression respectively of fibers ⅝-inch distant from bottom and top, and in the neutral axis, for a length of 6 inches in the center.

Under a load of 1,100 to 2,200 pounds,

The maximum compression was $\frac{4.5}{25400}$ of an inch.
The maximum extension was $\frac{5.3}{25400}$ of an inch.
The extension in center line of beam was $\frac{1}{25400}$ inch.

Under a load of 1,100 to 3,300 pounds,

The maximum extension was $\frac{3.1}{25400}$ of an inch,
And the extension in the center line of beam was $\frac{1}{25400}$ of an inch.

Prisms cut from these beams, showed ultimate compressive stresses, averaging 169 pounds per square inch for Beam No. 1, and 218 pounds for Beam No. 2.

The tests of the reinforced concrete beams were exceptionally elaborate. Extensions and compressions were measured on seven fibers of the beams by mirror extensometers allowing readings of 1-250,000 of an inch. Fig. 2 shows the location of these fibers, and readings were taken for a length of 6 inches in the center between the supports, marked a, and for a length of 6 inches, marked b, adjoining the length a. Altogether over 2,000 readings were recorded for each beam. Table No. 1 shows four series of read-

Test made on reinforced Concrete beams by Prof F. Schüle, Zürich

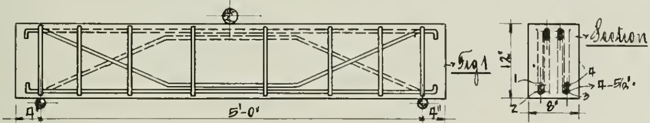


Fig 1

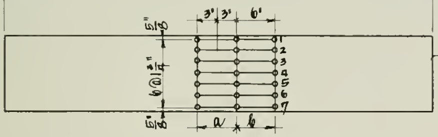
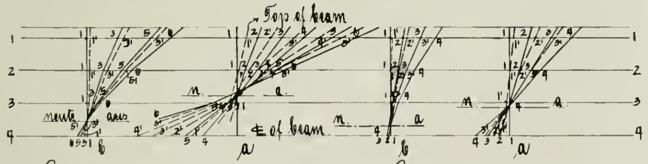


Fig 2

Beam A cracked 13200 lbs and broke at 34200 lbs

Compressions of Fibres in $\frac{1}{25400}$ of an inch in beam „A"

Load in 2000 lbs		1.1	2.2	3.3	4.4	3.3	2.2	1.1	4.4	1.1	4.4	1.1					on length a
Compress in Fibres	1	0	-0.55	1.18	1.74	1.27	0.92	0.15	1.79	0.14	1.77	0.10					
	2		-0.28	0.62	0.88	0.62	0.33	0.04	0.91	0.06	0.90	0.06					
	3		0.0	-0.02	-0.04	+0.01	+0.03	+0.06	0.00	+0.07	0.00	0.08					
	4		+0.28	+0.98	+0.88	+0.61	+0.38	+0.04	0.90	+0.07							
Load in 2000 lbs		0.55	1.1	2.2	3.3	4.4	3.3	2.2	1.1	1.1	2.2	3.3	4.4	1.1	4.4	1.1	on length b
Compress in Fibres	1	0	-0.16	-0.52	-1.01	-1.38	-1.01	-0.61	-0.21	-0.12	-0.52	-0.93	-1.26	-0.06	-1.30	-0.15	
	2		—	-0.22	-0.44	-0.65	-0.45	-0.24	-0.01						-0.66	0.00	
	3		—	-0.06	-0.14	-0.21	-0.14	-0.05	+0.02						—	—	
	4		—	+0.01	+0.02	+0.03	+0.01	+0.01	0						+0.03	+0.01	
Load in 2000 lbs		1.1	2.2	3.3	4.4	5.5	6.6	5.5	4.4	3.3	2.2	1.1	6.6	1.1	6.6	1.1	on length a
Compress. in Fibres	1		-0.57	-1.23	-1.86	-2.07	-3.31	-2.8	-2.24	-1.56	-0.95	-0.25	-3.34	-0.25	—	—	
	2		-0.23	-0.55	-0.81	-1.14	-1.40	-1.15	-0.89	-0.64	-0.30	-0.07	-1.39	-0.07	—	—	
	3		+0.04	+0.09	+0.17	+0.27	+0.54	+0.53	+0.44	+0.40	+0.34	+0.28	+0.61	+0.28	—	—	
	4				+0.91	+1.40	+3.37	+3.09	+2.71	+2.25	+1.60	+1.30	+3.54	+1.29	+3.60	+1.29	
Load in 2000 lbs		1.1	3.3	5.5	6.6	5.5	3.3	1.1	6.6	1.1	6.6	1.1					on length b
Compress. in Fibres.	1		-0.83	-1.75	-2.25	-1.84	-0.99	-0.12	-2.22	-0.15	—	—					
	2		-0.45	-0.93	-1.18	-1.01	-0.54	-0.06	-1.20	-0.07	-1.26	-0.14					
	3		-0.11	-0.23	-0.29	-0.26	-0.16	-0.06	-0.29	-0.05							
	4		+0.10	+0.22	+0.28	+0.25	+0.15	+0.02	+0.33	+0.06							



Loads between 1.1 to 6.6 tons

Loads between 1.1 to 4.4 tons

Extensions of Steel rods in $\frac{1}{25400}$ of an inch in beam „B"

Load in 2000 lbs	Number of rods 1	4	2	3	Load in 2000 lbs	Number of rods 1	4	2	3
0.55	0	0	0	0					
1.1	0.12	0.06	0.05	0.09	6.6	3.91	6.38	3.36	4.14
0.55	0.06	0.04	0.03	0.00	1.1	1.60	4.29	1.65	1.28
2.2	0.32	0.26	0.13	0.35	7.7	6.46	8.55	5.36	5.58
0.55	0.10	0.12	0.07	0.02	1.1	2.47	5.26	2.45	1.49
3.3	0.62	0.96	0.34	0.57	8.8	4.37	10.87	7.66	6.49
1.1	0.33	0.67	0.22	0.18	1.1	3.15	6.36	3.37	1.60
4.4	1.58	3.07	1.36	1.59	9.9	12.92	13.78	10.65	7.98
1.1	0.82	2.35	0.90	0.68	1.1	4.00	7.13	4.56	1.76
5.5	2.47	4.72	2.36	3.12	10.45	19.66	15.01	11.77	8.42
1.1	1.30	3.35	1.48	1.38	1.1	4.22	8.15	5.46	1.66

June, 1st. 04

Presented at the Meeting of the Western Society of Engineers ings taken on fibers 1, 2, 3, 4, of Beam A; two series for loads in intervals from 2,200 to 13,200 pounds.

The diagrams show the extensions and compressions magnified 1,167 times.

The fibers 5, 6, 7, showed very irregular extensions, being in no proportion to the compressions, but showing great variations on both sides of the beams, being for example nil on one side, and three times the compression of the fiber on the other side.

The Beam A cracked at a load of about 13,200 pounds, and ruptured at a load of 34,300 pounds by pulling out of the rods at the ends, which is easily explained by the extremely short extension of only 4 inches beyond the supports.

The unsatisfactory results obtained by the readings of the extensions of the lower concreate fibers of Beam A caused the measurements of the extensions taken directly on the steel rods in Beams B and C.

To this purpose ⅛-inch holes were drilled in the rods and the extensometers attached to them by means of small screws.

The table shows these extensions for the four steel rods of Beam B. No. 1 and No. 4 are the lower bent rods; No. 2 and No. 3 the lower straight rods. The first cracks appeared at a load of 12,100 pounds, and were in no connection with the holes drilled for the extensometers.

The tests made later on the steel rods when removed from the concrete, indicate that the limit of elasticity was reached at a load of 17,600 pounds. By inspecting the table we find that, the higher the maximum load in a certain series of tests, the greater is the remaining extension of the steel rods when the load is released. It is, however, certain, that these extensions disappear to a very great extent, if the interval between the loadings is sufficiently great.

Beam B broke at 36,300 pounds.

Beam C broke at 31,500 pounds.

The diagrams and tables show clearly the following facts:

1. The fiber stresses are, in no stage of the loading, proportional to the loads.

2. The vertical planes of the beams do not remain plane under the loads.

3. The neutral axis is not a straight line, but it is curved with the concave side towards the tension fibers.

4. The neutral axis is in the beginning above the center of the beam and is raised when the load is increased.

5. In each series of tests after the maximum is reached the fibers do not return at once to their former position when the loading is released; it is however established by other tests that these permanent changes of length tend very soon to a limit.

6. The percentage of the bending moment which is taken up by the concrete alone and by the rods varies with the load. If we multiply the extension of the rods given in the table for Beam B, be the modulus of elasticity, we obtain the stresses, and in multiplying by the theoretical depth of the beam, which can be taken for example from the diagrams, we obtain the bending moment taken up by the rods; the remainder must be taken up by the concrete alone. The percentages of the bending moment taken up by the steel rods in Beams B and C are given in Table No. 3.

TABLE NO. 3.

LOAD	BEAM B.		BEAM C.	
In 2,000 lbs.	Rods.	Concrete.	Rods.	Concrete.
1.1	9.0%	91.0%	15.6%	84.4%
2 2	10.0	90.0	21.4	78.6
3.3	14.0	86.0	33.0	67.0
4.4	30.5	69.5	40.5	59.5
5.5	39.6	60.4	58.8	41.2
6.6	45.7	54.3	76.2	23.8
7.7	56.0	44.0	82.0	18.0
8.8	65.0	35 0	84.5	15.5
9.9	75.0	25.0	90 0	10.0
10.5	78.0	22.0	93.0	7.0

We see that, at the time of the first crack, that is at 12,100 lbs., the rods take up only 43½ per cent of the bending moment, and the concrete although cracked, 56½ per cent, or more than ½ of the total bending moment.

In increasing however the load beyond that of the first crack, we find that the rods take up a rapidly increasing percentage of the bending moment, so that at 20,900 lbs. for example, the percentage is 78 per cent for the iron, and 22 per cent for the concrete.

We are used to assume that after the first crack the concrete does not contribute anything to the bending moment, but that all is taken up by the rods alone. In reality the crack does not cause any sudden increase of stress in the rods.

If we figure the stresses in the concrete according to any standard formulæ based on the elastic theories, we find the ratio of the stresses in concrete, and in the iron rods is 4 at a load of about 2,200 lbs., 11 at 8,000 lbs., 12 to 20 at the first crack, and 21 to 33 at the load of 20,900 lbs.

Gen. Wm. Sooy Smith—I will start by saying simply this: I know very little about reinforced concrete, although I have used concrete very extensively for a great many years. One thing I have learned to my satisfaction is that reinforced concrete presents some complicated questions. In the first place the results depend upon the quality of materials employed in making the concrete, and in the second place on the method employed in mixing, combining and using it. A great many who use concrete extensively hardly know the first principles of its manufacture, or its action after it is made. They hardly know that its value depends upon its high setting quality. They do not take into consideration the fact that there is a chemical action which depends largely upon temperature. Chemical action we know is almost always assisted by heat. If concrete is made at a low temperature it acts and sets very slowly. I was curious to know what the result would be in the specific behavior of concrete subjected to low temperature, and found that beyond a question if after freezing suddenly, it remained frozen until set and then warmed up gradually, it received hardly any injury, and would be about as hard as if made in warm weather. I found it a great advantage in freezing weather to heat the sand and also to salt the mortar. I have laid thousands of cubic yards of concrete with the mortar well salted, and laid it up right through the winter, just as if it were summer, and have never discovered that it did not set as well as it had been warmer.

There is one vital qnestion, it seems to me, lying at the very root of this whole subject—the use in reinforced concrete of two materials which are expected to act in harmony, while differing as they do in many respects. If the modulus of elasticity varies in these two materials, it becomes a very serious question as to how far the one having the greater elasticity will assist the one having less. There are other questions coming in. This question was raised by an architect, to whom I was presenting the idea of filling all the hollow columns of steel construction with concrete. It ought to be done for several reasons; the principal reason is to stiffen the columns; another reason is to prevent corrosion. I know from observations made on some of the oldest concrete on earth. I have never found a piece of iron in contact with concrete that had rusted. I had a piece of iron sent to me which was taken out of the foundation of the obelisk which was brought from Egypt and set up in Central Park, New York. This was known to have been in contact with concrete for 2,300 years, and was not rusted at all. So, if these hollow steel columns be filled with concrete, corrosion on the inside would be prevented.

Another thing—it is desirable to cover steel constructions with some preparation of lime. If you can make and apply a simple whitewash, it is cheaper than paint and it will prevent corrosion. Using a product called "asbestic," which is 90 per cent asbestos, and mixing that with lime into whitewash and putting it on steel, will both prevent corrosion and make it a wonderful resistant to fire. I have covered roofs in this city in that manner for fireproofing. Sparks or burning fagots may fall upon roofs, so protected, and burn out without any danger of igniting the roof. The architect to whom I suggested the filling of the columns said that it would do no good, because the steel and concrete are so different in their behavior that one will be ruined before the other is injured. I answered, this is not so, for when the column is filled with concrete it will afford the combined resistance of the two materials until the limit of elasticity of the more elastic one is passed. Its stiffness to resist bending will also be greatly increased and corrosion of its inside surface will be prevented.

Steel is the strongest material used in construction for resisting tensile strains, and concrete is one of the cheapest and best for resisting compression. So if we can combine the two, although we may not get full value of each of them, we get from the combination more than we could by the use of the same quantities used separately. And upon this very fact, it seems to me, almost entirely depends the value of this promising mode of construction—reinforcing concrete with steel.

Extract from the *Tecknisk Tidskrift*, a journal published by the Engineer Society of Stockholm, Sweden — translated by G. A. M. Liljencrantz:

"Among structural enterprises, the use of re-enforced concrete is becoming more and more employed. Among other applications the so-called 'beton poles' are at present a subject of great interest; such poles are said to have been used at the construction of some large and difficult foundations in Stockholm and to have received a high degree of commendation by experts. Tests have been made which show that these constructions have very great strength. At a talk which Civil Engineer E. Hjorth lately delivered before the Falu Engineering Club on this subject, there was exhibited, among other stereopticon views, one of a pole for electrical transmission, made like these beton poles, of concrete on a core of iron.

"As these poles have proved to be of considerable strength and durability, and are furthermore simple and inexpensive in manufacture, it seems that they would offer a suitable type for use in transmission of electric currents of high power, especially at the crossings of lines of traffic and for other purposes."

Mr. T. L. Condron, M. W. S. E. (by letter)—From Table III. of Professor Howe's paper it appears that the value of y_1 (the distance from the top of the beam to the neutral plane), was found to be from .35 d to .45 d. The value given for y_1 in the experiments when the extensometer cords were disturbed cannot be depended upon. In this same table he shows the stress in the bars according to Johnson's formula to have been from 50,000 to 66,000 pounds per square inch, when allowance has been made for tension in the concrete. As the concrete was invariably cracked on the tension side under the ultimate loads the concrete itself cannot be assumed to be taking tension at that time. In table IV. he gives the stresses in the bars, considering that there is no tension in the concrete, to be from 56,000 to 76,000 pounds per square inch. These latter figures agree closely with the readings of the extensometers.

If the neutral plane is taken to be .4 d from the top and the maximum stress in the steel taken at 60,000 pounds per square inch, which is practically the elastic limit of these bars, a very simple equation may be deduced for the ultimate strength of the beams, as follows:

d = Distance from top of beam to axis of reinforcing in inches.
b = Breadth of beam in inches.
P = Percentage of reinforcing $= \frac{100 \times \text{area of bars}}{b \times d}$
M = Ultimate moment in inch pounds.
A = Area of reinforcing in square inches.
T = Maximum tension in the bars = 60,000 pounds × A.
C = Total compression in the concrete.
y_1 = distance from top of beam to neutral plane = 0.4 d.
y_2 = distance from neutral plane to axis of bars = 0.6 d.

$$\begin{aligned} \text{Therefore } M &= Ty_2 + C\tfrac{2}{3}y_1 && (1) \\ &= T(y_2 + \tfrac{2}{3}y_1) && (2) \\ &= .867\ T\ d && (3) \\ &= 520\ P\ b\ d^2 && (4) \end{aligned}$$

Where the value of P is not less than 0.5, nor more than 1.0.

Applying this equation to the beams tested gives the results shown in table A.

TABLE A.

BEAM			MOMENT 520 Phd^2.	ACTUAL MOMENTS	PERCENTAGE DEVELOPED
No.	d	K			
1	4¼	.71%	80,000	94,300	118%
2	6¼	.72	176,000	212,200	120
3	8½	.71	320,000	402,700	126
4	12¾	.71	720,000	929,800	129
5	8¾	.57	272,000	311,900	114
6a	13	.58	610,000	607,200	99.5%
6b	13	58	610,000	639,300	102
6c	13	.58	610,000	666,300	104
6d	13	58	610,000	616,800	101
6e	13	.58	610,000	692,000	114 Gravel
7a	17¼	.58	1,080,000	1,189,400	110
7b	17¼	.58	1,080,000	1,152,000	106
7c	17¼	.58	1.080.000	1,142,900	106
7d	17¼	.58	1,080,000	1,006,400	93 Failed by shear
7e	17¼	.58	1,080,000	1,090,700	100 " " "
8	12¾	.69	700,000	756.500	108
9	19¼	.69	1,600,000	1,373,700	86 Failed by shear
11	16¼	.72	1,185,000	1.149.300	97

From these results the writer feels justified in offering the above equation as a simple and conservative formula for the proportioning of reinforced concrete beams where ordinary average rock or gravel concrete is used in proportions of 1 cement, 2 sand, 5 crushed stone (1½ inch and under with dust screened out); and deformed bars of at least 50,000 pounds per square inch elastic limit are used for reinforcing. The reinforcing area to be not less than 0.5 per cent nor more than 1 per cent.

In the above it is assumed that the compression stresses vary directly as the percentage of reinforcing or $f\ c = 2400 \times P$. Or for higher strength concrete in compression more steel should be used. Hence for:

$fc = 1200$ pounds per square inch, $P = 0.5\%$
$fc = 1440$ pounds per square inch, $P = 0.6\%$
$fc = 1680$ pounds per square inch, $P = 0.7\%$
$fc = 1920$ pounds per square inch, $P = 0.8\%$
$fc = 2160$ pounds per square inch, $P = 0.9\%$
$fc = 2400$ pounds per square inch, $P = 1.0\%$

Table B shows a comparison of the actual moments obtained by Prof. Howe with the theoretical moments for these beams from Johnson's formulas,* Hatt's formulas†, and the writer's, $M = 520\ Pbd^2$.

TABLE B.

BEAM No.	DEPTH IN INCHES.	PERCENTAGES OF THEORETICAL STRENGTH, ACTUALLY DEVELOPED BY TESTS.			REMARKS.
		Johnson's Formula *	Hatt's Formula. †	$M = 520\ Pbd^2$	
1	5	117%	112%	118%	½ in. Bars
2	7	122	117	120	" "
3	9½	125	121	126	" "
4	14	128	125	129	" "
5	10	110	108	114	¾ in. "
6a	14½	97	94	99	" " 29 days old
6b	14½	102	99	102	" "
6c	14½	107	103	104	" "
6d	14½	98	95	101	" " [gravel
6e	14½	111	108	114	" " 29 days old
7a	19	106	102	110	" "
7b	19	103	98	108	" "
7c	19	102	98	106	" " [shear
7d	19	90	86	93	" " failed by
7e	19	97	93	101	" " " " "
8	14	104	102	108	⅞ in. " [shear
9	21	90	82	96	" " failed by
11	18	98	94	97	1 in. "
Average.....		106%	102%	107%	

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* From results given in Table IV of Prof. Howe's paper.

† From results given in the Table of Mr. F. H. Bainbridge's discussion of Prof. Howe's paper.

CLOSURE.

Professor Hatt—It seems to the writer, that the discussion that has taken place is very valuable and justifies the presentation of the writer's paper, imperfect as that is. It is the fashion of some writers in Germany to present along with their papers what is called a "self-criticism." The writer would point out certain weaknesses in his position, at the same time commenting on certain matters touched up in the preceding discussion.

It is true, as Mr. Johnson has pointed out, that the assumption of the vertex of the parabola at the outer fiber of the beam is only justified when applied to the state of loading coinciding with the failure of the beam in compression. It certainly will not represent the conditions at early stages of flexure.

It seems to the writer that the inclusion of the tensile forces on the concrete in the moment of resistance at the time of the first crack, or preceding this crack beyond the point A, is not justified in view of the experiments of Professors Turneaure and Talbot, who have made observations that show the concrete on the tension face to be divided by minute fissures at a stage of loading corresponding to a stress in the steel of about 5000 pounds per square inch. Indeed, minute fissures exist before the beam is loaded; but these are not visible to the naked eye under ordinary circumstances in dry concrete. Nevertheless there must be a portion of the bending moment supplied by these tensile stresses on the concrete at early loads and an analysis which pretends to completeness should include the latter; but in view of the uncertainties of shrinkage stresses, etc., the added complication of formulas is not justified from a practical standpoint.

The use of the parabola for the compression area seems well in accord with experimental facts at rupture. The simplest method of computation of these beams is to multiply the total force on the steel by the assumed distance to the center of gravity of the compression area. This gives the moment of resistance of the beam. The maximum stress on the concrete in compression may then be computed from the shape of the compression area; or we may depend on co-efficients derived from tests to limit the amount of steel that should be used in case of concrete of various grades.

With regard to the first crack as a basis for fixing the factor of safety, it seems that what the writer has called a "first-crack" is, at least in the concrete used in the Purdue University experiments, a crack more serious than the first cracks noted by Professor Howe. This crack is no doubt influenced by the quality of the concrete and by the character of the loading. The writer's tests were made by applying the loads in increments, and relieving the loads to obtain the set; thus working the beams to a given stress, and back to zero. One cannot discuss this matter intelligently without having in mind the degree of cracking which an engineer would consider an evidence of failure in a structure. If we judge by the results of laboratory tests on relatively small masses of concrete, small cracks must be present, and must be accepted in this style of construction. Do they appear in actual structures? It appears that conservative designers load the steel reinforcement up to a stress of 16,000 pounds per square inch, corresponding to an elongation of one part in 2000.

We are told that the concrete will be divided by small fissures, and the latter begin to enlarge, it is said, at a stress of 5000 pounds per square inch. As a practical conclusion, it would seem that until these cracks become large enough to allow the rust-producing agencies access to the steel they are not serious. They only reduce to zero the moment of resistance of the tensile forces, upon which the designer does not rely, and from this point of view a serious crack can only occur when the metal of the reinforcement reaches its elastic limit.

It is possible to load a beam considerably beyond the elastic limit of the metal, if the concrete is sufficiently strong in compression before the maximum load is reached. Thus the beam may be practically ruined before the maximum load. The latter is not in such cases a proper criterion of strength. Is not, then, a serious crack, exposing the steel, the proper basis of comparison of the strength of two designs?

It appears to the writer that the values he has found for the constants of concrete are higher than those found by some other experimenters. All the materials were of excellent quality. While the cement was unusually strong, it showed a proper gain between seven and twenty-eight days in the form of mortar briquettes and concrete beams. The tension tests of neat briquettes were abnormal. The high modulus of elasticity is partly due to the method of calculation, and the values will be recalculated according to the ordinary method of measurement.

It may be said that the values are not higher than those quoted by Unwin from Hartig's tests, or than results obtained by recent careful tests at St. Louis. A tangent to the stress-strain diagram will not give values such as are listed. With reference to the point raised by Mr. Sherman, it should be said that a careful examination failed to show any notable decrease of the modulus of elasticity at higher stresses. We may hope that the several committees of the four societies at present co-operating in a report on the various elements of this subject will present uniform definitions and, after a review of the large body of data in existence, only a part of which has been published, will recommend values of constants for use.

Taking up the discussion in detail: Mr. Condron's simple equations seem to be in the right direction, although it is not right to avoid complications simply to save trouble. It seems that ordinary soft steel will not develop the compressive strength of 1-2-4 concrete. As soon as sufficient steel is placed in one layer in a beam with a view to developing this strength there is so much metal that failure takes places in shear in a horizontal plane just above the reinforcement.

However there seems no reason why the steel should develop the compressive strength of the concrete if, as is the practice of some designers, larger factors of safety are used for the concrete than for the steel.

Answering Professor Talbot's question, the writer plotted a large number of curves from the Watertown reports, and found the parabola to fit the results, the vertex of the parabola at the point of failure, and the curve running through the origin on a slope. This avoided the difficulty mentioned by Mr. Johnson, that a location of the vertex at the origin supposed an infinite modulus of elasticity at zero stress.

There are a number of interesting questions which form the fringe of this subject. Some of them may be of importance. It seems clear that the ultimate computed fiber stress on the concrete in compression fixed by the designer may be allowed to exceed the strength developed in an ordinary compression test, for the outside fibers are supported by a mass of concrete below, which has not yet reached its highest degree of strength. Again the presence of concrete under stress surrounding the steel reinforcement puts the latter under compound stress and a higher modulus of elasticity and elastic limit of the steel may result.

Mr. Mensch has raised the question whether or not the elongations measured on the side of a beam in the horizontal plane of the reinforcement may properly be used to compute the stress on the steel.

Comparing the strength of a 1-2-4 concrete beam reinforced with two per cent of soft steel, with a long leaf yellow pine beam, we find the following comparison:

Moment of resistance at elastic limit of reinforcement of reinforced beam equals 400 bh^2.

Moment of resistance of long leaf yellow pine at failure (modulus of rupture, 8,000 pounds per square inch), equals 1333 bh^2.

HYDRO-ELECTRIC POWER DEVELOPMENT AT AND NEAR JOLIET, ILL., USING CHICAGO DRAINAGE CANAL WATER.

By Thos. T. Johnston, M. W. S. E.

Presented Sept. 30, 1903.

Years before the Chicago Drainage Canal was actually undertaken, much was said concerning the water power which would incidentally be created; much more perhaps, than the facts justified. However, the canal is in a large measure completed and water is flowing through with the result that it is feasible to develop four water power plants at a cost which will permit of commercial utility. One is at Lockport; one is at Jackson street in Joliet; another several miles below central Joliet, and there is one at Marseilles. The aggregate electrical horse power practicable is about 60,000, if a flow of 600,000 cubic feet per minute from the drainage canal can be had. This flow may not be had for some years to come, but is near enough at hand to justify hydraulic works for utilizing it in any constructions which may now be made, even if full machinery installation be postponed. The flow required by law at this time is 360,000 cubic feet per minute, and such a flow and possibly a little more will doubtless have existence in a year or two.

That one, of the four feasible powers, which is located at Jackson street in Joliet, has been developed. The hydraulic development is suited for the use of 600,000 cubic feet of water when it is available, and mechanical installation for 500,000 cubic feet is installed, the work having been completed in January, 1903. A part of this power is now being transmitted 34 miles to Chicago, as will presently be explained, at an initial voltage of 35,000.

In June, 1898, the writer was called in by Mr. John L. Norton, President of the Economy Light and Power Co., of Joliet, to design and undertake the construction of a plant at the Jackson street location in Joliet; hereinafter this will be referred to as the Economy plant. In July of that year the general plan was evolved, involving the arrangement of dam, head race, power house, tail race, and size of units. In August a litigation involving this power arose between the Sanitary District and the State of Illinois, which led to the withdrawal of the writer from the enterprise, because he was at that time assistant chief engineer (and later consulting engineer) for the Sanitary District. The State of Illinois is the owner of the power at this site and leases it to the Economy Company. The controversy turned on the elevation which should be given to the crest of the dam, in view of the flow of water which the drainage canal would cause. The court decided that the crest of the dam, which was an old one, constructed to facilitate navigation in the Illinois and Michigan Canal, must remain unchanged. This decision made it difficult to dispose of flood waters on the part of the Sanitary District, which difficulty was overcome by an arrangement being made to accomplish the desired end incidentally with the construction of the power plant as designed by the writer, and the court entered a consent decree accordingly. The arrangement stipulated that the State should pass water through water wheels or overflow gates in any power plant which might be built, and in such manner that the water level above the dam should not raise higher than −36.00 Chicago datum. The capacity of the water wheel installation is substantially equal to caring for all surplus waters in flood times, and, in case the wheels be not in operation, gates in the rear of the wheel bays will accomplish the same result. The Sanitary District, on its part, was required to excavate the tail race which will be described further on. Another element of the consent decree was the requirements to feed the Illinois and Michigan Canal, at the opposite side of the river with a flow of 30,000 cubic feet per minute. This is accomplished by means of a tunnel under the river, built by the Sanitary District, who also built the dam after the designs by the writer.

The litigation being concluded, the writer resumed his charge of the work. In October, 1900, the temporary unit was put in operation. In July, 1901, three other units were completed and in January, 1903, two others.

There exists in the DesPlaines river, at or near Joliet, two other water power possibilities, the one, several miles above and the other several miles below the plant of the Economy Light and Power Company. The one above may be developed under a head variously estimated at 28 to 34 feet—we may say 32 feet for present purposes—and is known as the Lockport water power owned by the Sanitary District of Chicago. The one below may be developed under a head of about 20 feet, and is known as the Hickory Creek water power, and is owned conjointly by the Sanitary District, the State of Illinois, and what has been styled as the Gaylord syndicate. The Gaylord people have title to 10 feet of the head on both sides of the river, while the title to the other 10 feet is divided between the State and the Sanitary District. It will be only at the end of a litigation, part of which is now under way, that this Hickory Creek power can be developed under 20 feet head, though nothing can intervene to prevent Gaylord from developing the power under 10 feet head.

Mention has been made of the intention of the Sanitary District to develop these two water powers. In this connection the following published statement as to cost and revenue is quoted.

"The cost of the Lockport development amounts to $2,750,000, in which is included the cost of the pole line complete for transmission to Chicago. The cost of the Joliet development, which also covers transmission, will be $990,000, or a total for the two developments of $3,740,000. With our flow of water at its maximum of 600,000 cubic feet per minute, the resulting power on the heads which we can secure at the respective sites will be for Lockport (32 feet head) 36,352 gross horse power and at Joliet (20 feet head) 22,720 gross horse power.

"I use only 75 per cent of the gross horse power when figuring what will be available for service. On this basis we would have at Lockport 27,264 net horse power, at Joliet 17,040 net horse power. I base my estimate of revenue on $25 per annum per horse power for 24-hour horse power. Even on these conservative figures the revenue from Lockport power would be $681,600 and from Joliet $426,000, or a total annual revenue of $1,107,600 as a minimum annual return on a maximum investment of $3,740,000. This work could all be completed within two years from the time the contracts are perfected."

The writer simply quotes these figures, without any intention of criticising or approving them, as a basis for some discussion of what may be accomplished by the transmission of this power to Chicago for municipal uses, or by otherwise using it. He is inclined to differ from the figures quoted in one particular only, namely: 70 per cent of the gross horse power, instead of 75 per cent should have been used in arriving at the number of horse power, the estimated value of which is $25 each. The reason for this is that a combined efficiency of water wheels and electric generators exceeding 70 per cent cannot be attained in practice, when the extraneous losses due to electric cables and water wheel settings and obstructions, which are not included in guaranteed efficiencies of water wheels and electric generators, are considered; and therefore only 70 per cent of the gross horse power can be had at the switch board, where salable horse power is measured. The writer has designed two water driven electric plants working under substantially 35 feet head and has not felt justified in estimating quite as much as 70 per cent combined efficiency of water wheels and generators, switch board measurement being contemplated for power output.

MUNICIPAL USES.

The proposition to transmit this Sanitary District or Drainage Canal power to Chicago for municipal purposes is purely and simply of a commercial nature. The municipality in this matter, is in the same position as the individual investor in industrial enterprises. The paramount question is: Will it pay, and, if so, how much? The processes of figuring the financial merits of the proposition will be just the same as if it was a private enterprise.

It will be sufficient to consider the matter in relation to the Lockport development alone, since the amounts of power considered are so large that there would be no economies eliminated by considering these two water powers together.

The municipality has substantially two uses for power: First, for water supply pumpage; second, for electric lighting. It has been said that it might use power for its street car uses, but this is so problematic and far in the future that it need hardly be considered at this time. All other municipal uses of power are very small or not applicable.

The application of electric power to the existing water works pumping engine is practically out of the question. The speeds are such that a belt or gear or rope drive would be needed between the motor and pump. None of the pumps are built with a view to such a connection, and in the case of nearly all of them it is substantially impracticable to modify them, that such a connection could be made. From the point of view of the electrical engineer, it is easy enough to install motors. From the point of view of the hydraulic engineer, it is not clear how the application can be made. The author has been in intimate contact with the problem at Bridgeport, on a large scale, and has also had much to do with the Chicago water works engines at one time or another, and is of the opinion that the application of electric drives to the existing pumping engines is substantially impracticable.

However, without arguing this side of the question further, it may be stated that there is an objection to the use of water power electricity for water works pumping that is more serious than any financial question, and that is the absolute certainty of interruption in the operation of the power plant at Lockport by anchor ice. With the power plant at Lockport shut down, the water supply of this city would be stopped. And there seems to be no way of defeating the anchor ice. There have been several shut downs lasting for some hours at the Economy Light and Power Co. Plant during this and last winter. The water enters the wheel bays but does not congeal until it comes in contact with the iron or masonry, and then ice builds up quickly. We have had it completely block the entrances to the water wheels while running and completely cover the wheels so they could not be seen. The action is so quick that no steam driven adjunct would be a safeguard. Contingencies of this kind are hardly to be tolerated, and would seem to eliminate water power electricity from application to the water works pumping engines. It may be stated also, that the improvements in steam performance of pumping engines in the last few years, by use of high steam pressures and superheated steam and other things have reduced the horse power cost to something like $30 per year, and the end is not yet, as may be proved when the new pumps the city is so wisely installing at the Chicago Avenue station are tested. Now, take power on the switchboard at Lockport at $25.00 per horse power per year, and let the losses between Lockport and the pumping station be 15 per cent, then the value of the power at the pumping station will be $29.41 per year. If this be true, it is not clear where the advantage in the transmission comes in.

The assumption of 15 per cent loss is justified on the basis that the Lockport power would be transmitted to some central point, as near the heart of the city as possible, and at a very high voltage, say 35,000. To this point the losses, including those through the transformer, would be 10 per cent. At this point the voltage would be stepped down to some intermediate amount, say 12,000. From this point the power would be transmitted on feeder circuits to the several pump houses, thus involving another 5 per cent loss. It would, of course, be utterly impracticable to run 30,000-volt circuits through the city, nor could the transmission be profitably made from Lockport to Chicago at the lower voltage.

The only other substantial use the municipality has for electric power is for street lighting, that is for arc lights. It is claimed that there will be 36,352 gross horse power in the water column at Lockport. As a matter of fact the present legally required flow through the Drainage Canal will give but 24,000 gross horse power. However, let the greater amount be assumed for the present. Taking the combined efficiency of water wheels and generators at 70 per cent there will be 25,446 horse power on the switch board at Lockport. The next question is as to how much of this power can be delivered at the point of application in Chicago. The nature of the case, as will appear further on, is such that we may assume a 35,000-volt transmission to the intersection of Ashland Avenue and Archer Avenue. Here there would be a step-down to about 12,000 volts, and thence a distribution in feeders to points of application where there would be another step-down transformation. It can hardly be contemplated, that with main line losses, three transformer losses and feeder line losses, more than 85 per cent of the Lockport power will reach the point of application of power. That is, there will be delivered 21,629 horse power.

There is little doubt, and certainly it involves the least cost for installation, but that enclosed series alternating-current arc lamps would be adopted for the service. The next question then, is as to the number of lamps the power would serve. There have been installed recently, two 25-light circuits of such lamps in Joliet, one lamp to each block, and both circuits near by the power house, and we find that by switchboard measurement at the power house, each lamp uses power at the rate of 0.67 horse power. On this basis, the power delivered at the point of application in Chicago, would serve 32,282 lamps. If these lamps be placed one at every street intersection, and there be sixteen blocks to the mile, which is the general rule, then an area of 112.5 square miles would be covered, which is not much different from the present populated area of the city. This would mean exceedingly intensified lighting, but either it or its equivalent would have to be installed to use the power, and the use of all the power must be contemplated since it is contemplated that substantially all the water driven electric plant is to be installed forthwith. It would certainly be the least expensive arrangement to make for installation and operation. Now, as to installation and operating expenses of such a system, our experience in Joliet indicates that, for an aerial construction the cost of lamp installation including poles, wire, lamps, regulators and minor fittings, is not less than $80 per lamp. With underground wires, it is of course much more, but this element of cost will not now be considered. At $80 per lamp the installation cost would be $2,582,000, neglecting the cost of feeder lines. It appears from the reports that the city has been expending about $100,000 per year in extending its electric light system, at which rate it would take over 25 years to make the installation needed to use the the Lockport power, to say nothing of underground construction and of rising to the increased operating expenses.

The essential feature, however, is as to the cost of power to the city for electric lighting, water power electricity being used on the one hand, as against steam power on the other hand.

The tax payer is asked to invest his money in this undertaking with a view to profit. The dividends are to appear in the shape of reduced taxes for other purposes. If he does not put his money in this undertaking he would have it available for other enterprises. It is therefore proper to treat the matter from an investment point of view.

The items which contribute to the cost of power to the municipality will, in general, be as follows:

1. Interest on Investment.
2. Depreciation and Maintenance.
3. Operation of Plant.
4. Rent.
5. Going Concern Charges.
6. Miscellaneous.
7. Sinking Fund or Equivalent.

Item 1 needs no discussion.

Item 2 refers to that expenditure which is needed currently and that money which is to be set aside annually for future expenditure, in order to keep the plant up to a uniform standard of usefulness.

Item 3 refers to fiscal office expenses and power house expenses.

Item 4 refers to the rent the municipality (Chicago) must pay the Sanitary District, which is assumed to be the same as anybody else would pay to the district. It is a revenue that the tax payer must relinquish, if the item be not considered, and therefore it should be charged against the cost of power to the municipality.

Item 5 needs some explanation. There can be no question but that the interest on money expended during construction up to the time of operating the plant is a proper item to add to capital account.

If the construction be done in two years and the interest rate be 4 per cent, and the expenditure be made uniformly, then 4 per cent of the cash investment may be added to the amount expended to arrive at the total investment. Thus, if $2,750,000 be the cash investment, then adding 4 per cent to this, the total investment becomes $2,860,000. This is true whether the money be raised by taxation, or by bonds. Now, if upon completion of construction, the whole plant be put in operation substantially at once, then there would be no further increment to capital account, assuming, of course, that no accident or other causes made necessary any expenditures or losses beyond those involved in the other items of cost of power.

The nature of the case is such that substantially the whole cash investment is to be made in two years or such a matter. It has further been shown that, in order to use all the power, heavy investments must be made by the municipality to install apparatus and a heavy operation charge be incurred. These are so large that there can be no hope of attaining to them short of some years, doubtless ten years or more after the plant is in operation. During this period a portion of the plant must be idle, the magnitude of such portion diminishing as time goes on and until all the power is used. Meantime the taxpayer is getting no profit from the idle portion of the plant and is a loser to that extent, unless, as has been contemplated at one time, that rental price for the whole power be paid from the time of completing construction, and then the municipality is the loser. Whether taxpayer or municipality is loser makes no difference. The loss exists and for convenience may be assigned to the municipality in the form of excess rental. The accumulated amount of this excess is money invested in the production of the power and should be added to capital account, or, what is the same thing, the interest on such accumulation may be entered as an annual charge for cost of power. The name to be given to this interest item is usually stated to be the expense of creating a "going concern." It has been recognized by arbitration boards and by the courts as proper in evaluating water works plants and is conceded to be between 15 per cent and 20 per cent of the cash investment in some plants. The interest on this 15 per cent or 20 per cent is the annual charge against the cost of power contemplated in item (5) above. If it requires ten years to bring all the force into use, at a uniform rate, then half of the rent paid in the ten years would be paid without any return for it. It is money put into the cost of power on which there has been no return, and it has been put in for all time. Interest on this permanent investment should therefore be a charge against cost of power for all time.

Item (6) refers to legal expenses, administration charges, such as the proportional charges of expenses of Trustees of Sanitary District, expenses for damages to life and limb of employes, and other unforeseen things. It may properly include a consideration of taxes, for reasons as follows: It has in general, been governmental policy to encourage the development of public potentialities, thereby creating wealth, creating employment for more people, and increasing the taxes available. New, if this power is to be used by the municipality, it cannot be instrumental in creating taxable property, and the taxes which would otherwise be collected will be lost, and should be a proper charge against the cost of power.

Item (7) is one frequently required in the financing of industrial enterprises, and has in view the possibility that the plant, although it be kept up to a uniform state of usefulness as contemplated by item (2), still, after a certain length of time may pass out of use, say by the substitution of something better, without having any salvage value that will restore to the investor his original investment in it. It is not intended by the writer to assign to it any financial value herein, but he wishes to mention it for what it is worth. He will assume that the plant has, with the application of items (1) to (6) inclusive, an indefinite life.

It is in order now to assign money values to these items, and it will simplify matters somewhat to assign these values to both water driven and steam driven plants conjointly, and summarize the results in parallel columns.

ITEM I—INTEREST ON INVESTMENT.

Water Driven—The estimated cash investment is stated to be $2,750,000 and time of construction two years. Adding interest on investment during construction—say 4 per cent—and the total becomes $2,760,000- The interest charge being taken at 4 per cent would be $114,400 annually.

Steam Driven—The magnitude of the power under consideration is such that a number of steam units may be contemplated, each of which would ordinarily be called large—so large, that steam turbine driven generators may be considered, at a cost not exceeding $70 per horse power, at point of application of the power—this cost including real estate, buildings, boilers, engines, generators, switchboards, and all construction costs, including interest on investment during construction, up to point of application of power. It is to be noted that a steam driven plant, being made up of a number of units, located at several more or less distributing stations, need not be constructed all at one time, and the construction period, when interest charges accumulate, would be much shorter than for the water driven plant. At $70 per horse power, and with 21,629 horse power to generate, the total investment would be $1,514,000. The interest charge, taken at 4 per cent, would be $60,560.

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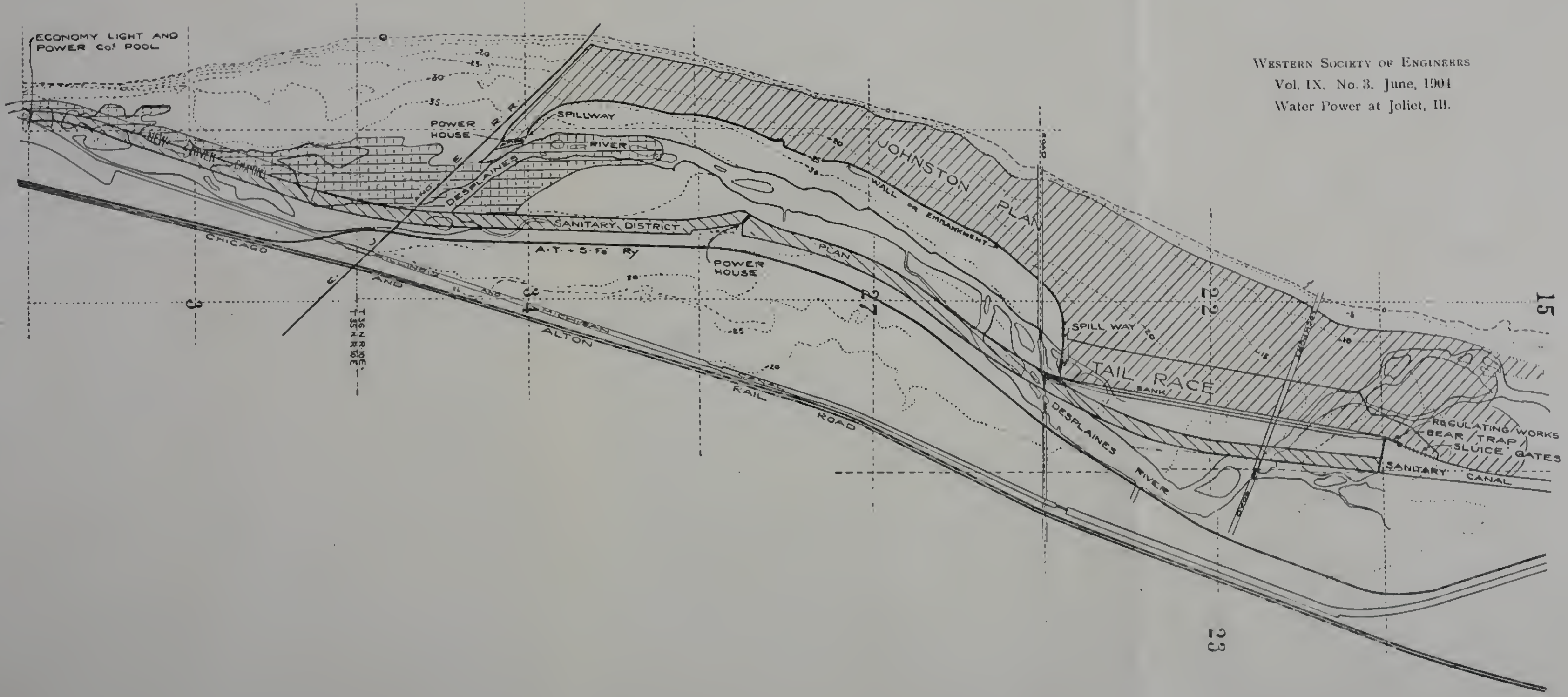
Water Power at Joliet, Ill.



ITEM 2—DEPRECIATION AND MAINTENANCE.

Water Driven—Say 2 per cent, or $57,200 annually.

Steam Driven—Say 5 per cent, or $75,400 annually.

Modern steam driven plants should easily have a life of 20 years.

ITEM 3—OPERATION OF PLANT.

Water Driven—Say $20,000 per year, including heating, lighting, cleaning trash racks of debris and ice, care of pole line and all miscellaneous power house charges. The item is so small that any error in it is of no import and further discussion is unnecessary.

Steam Driven—It is proper, in making the comparison in question, to contemplate the most modern and high class steam driven electric machinery. This seems to involve steam turbine driven generators, working with very high pressure superheated steam under the extraordinary economy developed in the past year or two by such machines, and involving high efficiency at fractional loads. The units will be large enough to justify the highest type of boiler construction and economic performance. With such machines the cost of 24-hour power should not exceed $24 per year for operation Arc lamps are not in use, even with the most lavish use more than ten hours per day as an average, so that 10-hour power is to be considered, the cost of which for operation should not exceed $12 per horse power. There being 21,629 horse power, the annual operating cost, when all its power is in use, will be $259,548. It will, of course, be some years before such an operating expense will be involved—say ten years, at least—so that, if this figure be taken, it means a charge against steam power amounting to $1,297,740 in excess of what will actually be paid if the power came into use at an uniform rate. However, it will be allowed to stand, and to some extent justifies further the "going concern" charge against water power.

ITEM 4—RENT.

Water Driven—Nearly five years ago the Sanitary District advertised for bids for leasing the undeveloped water power at Lockport, and was offered $4 per horse power per year, based on the gross horse power, if the writer remembers rightly, and the plant to belong to the Sanitary District at the end of fifty years. In any event, it is worth more now. Those uses of electric power which have led to a ready market for it have substantially come into existence since those bids were received. Less than two years ago it seemed as if not more than half the output of the Economy Light & Power Company could be marketed at Joliet, and this fact led to the construction of an expensive pole line to Chicago to furnish 500 to 600 horse power to the State Canal Commission. If it was to be done again, this pole line would not be undertaken. In view of these things, it seems to the writer that a rental value of $6 per horse power for the gross horse power is fair to have in view. There being 36,352 gross horse power, the annual rent should be $218,112.

Steam Driven—No rent item is involved for steam driven power.

ITEM 5 — GOING CONCERN CHARGES.

Water Driven — The rent paid for ten years will be $2,181,120, and if the power came into use at an uniform rate during this period, then the excess rent paid will be $1,090,500, the interest on which, at 4 per cent, will be $41,822 annually. Furthermore, the interest on investment will go on for ten years and amount to $1,144,000, thus adding half this amount to capital account, or $572,000. The interest on this amount is $22,880.

The going concern charge will therefore be $64,702 annually.

Steam Driven — Since a steam driven plant may be installed gradually, to all intents and purposes, as the power is required, no charges are involved.

ITEM 6 — MISCELLANEOUS.

This item may be omitted on the ground that it applies with substantially equal force to both types of plant.

ITEM 7 — SINKING FUND.

It has already been said that this item will not be considered.

SUMMARY.

	Water Driven.		Steam Driven.	
	Annual Rate.	Annual Charge	Annual Rate	Annual Charge
1. Interest on Investment..........	4 per cent	$114,400		$ 60,560
2. Depreciation and Maintenance..	2 per cent	57,200		75,400
3. Operation of Plant.........		20,000		259,548
4. Rent..........................	$6.00	218,112		None
5. Going Concern Charges.........		64,702		None
6. Miscellaneous..................		Omit		Omit
7. Sinking Fund..................		Omit		Omit
Total...............		$474,414		$395,508

It appears from these figures that the steam driven development has a less annual charge by $78,906 per year, and that, as far as municipal use of power is concerned, the tax payer, either of the sanitary district, or the municipality, will lose that much money annually by using the water driven electricity. Water driven electricity will cost him about $22 per horse power for ten hour power, and steam driven power $18.

The conclusion is that it is impracticable to apply the water driven electric power to water supply pumping, and it is less expensive to apply steam driven power to electric lighting; these are substantially the only uses the municipality has for power.

It may be asked what influence the existing electric light plant has on the question. Evidently, it has none. If the city had the means at hand, it would doubtless pay to replace it with something more modern, which gives rise to the inquiry as to where the city would get the money to use this Drainage Canal power, if it was developed.

Unless the Sanitary District goes into the sale of power to private consumers, probably outside of the city and outside of Cook county, it does not seem that there is any commercial advantage in the development.

COMMERCIAL USES.

The financial merits of transmitting the power to Chicago for general "commercial uses" are as follows:

This feature of the matter introduces some new elements, not brought out in discussing the merits for "municipal uses."

(A) *Interest Charges*—Applied to "municipal uses," the writer used 4 per cent as the rate, assuming that for "municipal purposes" money has that value, or the municipality could borrow at that rate for that purpose. Borrowing money is not contemplated, however, and the real and proper criterion might better have been—"What would the money be worth to the taxpayer if not invested in the power proposition?" In answer to this, it might be said that sooner or later the money must be invested anyhow for power in some form—either steam or water driven—and the value should be based on 4 per cent, or the rate at which the municipality can borrow it. No such answer can be made, if "commercial use" of power is to be considered. The straight business method is to figure the matter just as a private corporation would, and assign an interest rate corresponding to the value of the money for the purpose for which it is to be used, which in this case is known to be not less than 5 per cent. The taxpayer's money is certainly worth 5 per cent to him invested in other industrial lines akin to power plants. This figure will now be used.

(B) *Depreciation and Maintenance*—In discussing this feature in reference to "municipal uses," 2 per cent was used, but contemplated that the power would be delivered in one large lump to the municipality, and that the depreciation and maintenance beyond that point would be borne by the lighting, and not be charged against the power. It is quite different in the case of "commercial uses" where the power has to be delivered to the consumer at points of use, and feeder lines, various transformers, and other things must be looked after. Capital account should be increased, and the items involved are of a nature in which depreciation is very heavy. Underground construction is involved, as also insulated wire. In view of these things, I estimate that the "depreciation and maintenance" accounts should be made 3 per cent instead of 2 per cent.

(C) *Capital Invested*—The capital invested on account of power will be larger than if for "municipal uses" on account of the necessity of delivering the power to consumer at point of consumption. Feeders, transformers, switchboards, underground construction, rotary converters, motors, etc., etc., are involved in the expense, which will be greater or less according to circumstances. The total capital to be invested on this account may reach $1,000,000, or may be less than half that amount. The item will be omitted now, as time is not available for a closer investigation.

(D) *Taxes*—Taxes should be charged against the cost of power in cases of "commercial uses," for if the taxes are not paid, still they are lost, because a private corporation would pay them if the water power, as a whole, was leased.

(E) *Operation*—This should be increased to $40,000 for "commercial uses," in distribution account, collection of rates, and miscellaneous.

(F) *Rent*—Obviously, this should stand.

(G) *Going Concern Charges*—A proper policy will retain this item, as will be shown farther on.

(H) *Competition*—No question of cost of steam driven power is involved in case of "commercial uses," except that it limits the revenues to be derived from water power electricity. It can be shown that large consumers could not afford to pay over $20 per horse power per year, measured at the switch board at Lockport, so if larger prices are expected, smaller consumers must be contemplated. This would increase the cost of installation, operation, depreciation, and other items.

The following general statement may be made:

Cost—Omitting from capital account the expense of distribution of power.

1.	Interest at 5 per cent on $2,860,000	$143,000
2.	Depreciation at 3 per cent on $2,860,000	85,800
3.	Operation	40,000
4.	Rent	218,112
5.	Going Concern Charges	64,702
6.	Taxes	30,000
	Total	$581,614

Power delivered 21,629 horse power, making the cost $26.89 per horse power per year.

Cost—Estimating only $500,000 added to capital stock on account of expense of distribution of power.

1.	Interest at 5 per cent on $3,360,000	$168,000
2.	Depreciation at 3 per cent on $3,360,000	110,800
3.	Operation	40,000
4.	Rent	218,112
5.	Going Concern Charges	64,702
6.	Taxes	30,000
	Total	$631,614

Power delivered 21,629 horse power, making the cost $29.20 per horse power per year.

The horse power cost would be still more if the capital account is to be increased further on account of distribution, which is more than probable.

As to the propriety of retaining the "Going Concern Charges," it may be said that the output of the plant may be sold very soon, and that the charge is too heavy. In reply, it may be said that the investment to be made is for developing the full power due to 600,000 cubic feet per minute flow; whereas the existing flow is much smaller, and it will be some years before the full flow can be attained. The charge should therefore stand, because, even if the market does or can absorb the power at once, still, it cannot be developed for sale earlier than at an uniform rate of increase through ten years, or the equivalent thereof, because of lack of water.

What has been said in this connection has been based upon an available working head of 32 feet, which, as will be shown further on, is too large by 10 per cent or more; so that, as a matter of fact, the costs of water driven power above stated are too small by perhaps 10 per cent.

If, by any means, the cost of installation can be reduced to $1,000,000, and the writer is of the opinion, as will presently be discussed, that it can be, then the commercial utility will be entirely different, and can be made profitable in a minor degree for electric lighting, and in a major degree for miscellaneous commercial uses.

Without tabulating the details, as already done with a construction cost of $1,000,000 in view, which anyone can do with the data already given, it will be sufficient to state the results that will follow in comparison with a cost of $2,750,000.

1ST. MUNICIPAL USES.

Cost per Horse Power.

Water Driven Cost. $2,750,000	Water Driven. Cost. $1,000,000	Steam Driven.
$22.00	$15.22	$18.00

2D. COMMERCIAL USES.

Cost per Horse Power. Switchboard Measurement.

Water Driven. Cost. $2,750,000	Water Driven. Cost. $1,000,000	Steam Driven. Not Considered.
$26.89	$19.40	

If sold at $25 per horse power per year, there is a good profit if installation cost $1,000,000, and a loss if the cost of installation be $2,750,000.

AN ALTERNATIVE PROJECT.

The official proceedings of the Sanitary District of Chicago, April, 1901, contains what purports to be an historical review of water power matters between Lockport and Joliet, known as the Lockport power, which is signed by seven members of the Board of Trustees. In this, the writer is credited with having presented a plan in 1899 for developing the Lockport power, in a partial way, at a cost of $600,000. This statement is not correct. What the writer really did is stated in what follows.

The Sanitary District, in 1899, contemplated leasing the undeveloped power to the highest bidder, and advertised for and received bids, which were not accepted. One of the bidders obtained permission of the chief engineer of the district to have the writer, who was then assistant chief engineer, to estimate the cost of developing the power in question, and to design a plan for the work. This he did, and at that time estimated the total cost at $1,250,000, but now places it at $1,000,000, including mechanical installation and pole line to Chicago.

The general elements of the design contemplated are indicated upon the accompanying map, which shows the valley of the Des Plaines river from a point some distance above Lockport, down stream nearly to the site of the Economy Plant already mentioned.

Note may be made particularly of the location of the regulating or controlling works at the end of the Drainage Canal, and of an embankment at the east of the so-called "tail race" extending from the bear trap dam southward to the wire mill highway.

It will be clear that, as far as the use of Drainage Canal water is concerned, and there are periods of time when it is the only water available, the maximum head available for water power will be the difference in level between the water surface in the end of the Drainage Canal and in the pool just above the site of the Economy Plant at low water. These levels are both variable and therefore the head available will be variable. However, for commercial utility, that minimum head available which will endure for some days, and which will be recurrent, say annually, is that head which should properly be adopted for the basis of a power design.

The maximum flow from the Drainage Canal is that which will take place when the water surface therein is parallel to the bottom of the channel, and when the Drainage Canal work is complete, so as to permit its full flow from Chicago, the integrity of the elements of the canal pertaining to sanitation being preserved. Then the level of water surface at the end of the canal will be about six feet below datum when the level of Lake Michigan is at Chicago datum. However, the lake level for periods of considerable length, and recurrently, drops to two feet below datum. An annual level of the lake, 0.58 feet below datum, is recorded. Again, the Drainage Canal is becoming more or less diminished in cross-section by deposits of debris, and in spite of the dredging which must in course of time be resorted to, its full prism cannot be maintained. Furthermore, in the winter months the flow will be more or less obstructed by ice, even if it be kept well broken up. It would seem, therefore, that a water level at the end of the canal higher than –8.00 feet Chicago datum cannot properly be used for the basis of a design. This is the level determined by the writer when he calculated the grade of the canal.

The level of the water in the pool above the Economy Plant, at flood time, is limited by regulation to –36.00 feet Chicago datum. Therefore, the head available at flood times will be limited to 28 feet, which will be the determining head, according to the design upon which the Sanitary District asked bids for construction. However, if the design the writer is about to descrbe be contemplated, then it is not the determining head, because under the lower head at flood time there will always be enough water to create more power than can be created under a possible higher head at low water. The low water level of the pool above the Economy Plant may be that which will exist if the Economy Plant be substantially shut down, or running at very light load, and nearly all the water be flowing over the dam. The Illinois Steel load supplied from this same source, is at times shut down for a considerable period when overhauling the mills, and at times the street car load, also from this source, is very light. Also, the lighting load is off most of the time. This level will doubtless not vary materially from -38.00 feet, Chicago datum. It follows, then, that at low water the determining head will be substantially 30 feet.

From these two determining heads, the slope in head and tail ways must be deducted, and this slope may carry from one foot to several feet, according to the design. The real head available for a design not using flood waters will then be not greater than 27 feet, and the head for a design using flood waters will be not greater than 29 feet. Slope in raceways being the same, a design using flood waters will create about 5 per cent more power continuously than a design not using flood waters.

The volume of water available at time of maximum proper head will be the flow from the Drainage Canal, which will be the same for all designs and may be taken to be 10,000 cubic feet per second, or 600,000 cubic feet per minute as it is usually expressed.

Storage water in the Drainage Canal is out of the question, since it will necessarily militate against the usefulness of the canal for sanitation, and at times create velocity of flow prohibited by law and bad for navigation, and consequently, any corresponding variation of head water level or volume of flow, is out of the question.

It is concluded, from what has been said, that a head water level substantially different from -8. feet, Chicago datum, cannot properly be considered, and, as far as water power is concerned, a higher level of water in the pool above a power house would be of no use.

What has been said relates to a design fitted to a flow of 600,000 cubic feet through the Drainage Canal. Suppose, however, that such a flow will not come into existence for some years, and consequently the level of the water at the end of the canal will be higher than -8.00 feet Chicago datum. It may be desirable therefore, to fashion the permanent design so that until the flow reaches 600,000 cubic feet per minute, the lesser flow can be utilized under the several feet more head which will pertain to it. This is in the nature of a temporary arrangement, but should be considered.

A general plan, which is the same as conceived by the writer in 1899, and in accordance with which he has made several expert reports since, is indicated on the accompanying map, at the west side of the valley to the right of the river. Proceeding from the end of the Drainage Canal at the side occupied by the Regulating Works and Bear Trap Dam, the line of the bank at the east of the "tail race" is followed to the wire mill road. Thence a line to the west is traversed, crossing the "tail race," and thence along a line located on a contour of the valley at -26.00 feet, Chicago datum, nearly to the E. J. & E. R. R., where a rather abrupt turn is taken down the hill until the river bed is reached, as indicated, and here is located a power house. Along the lines thus described a wall or embankment is proposed, confining the water to the west bluff of the valley, as indicated by the hatched area. While this area looks quite large, there is but a shallow depth of water proposed on much of it, especially at the north end.

Having in mind for the present a flow of 600,000 cubic feet per minute through the Drainage Canal, the merits of a wall may be considered, made of Portland cement concrete masonry. The writer, when building the Swan Fall power plant on the Snake river in Idaho several years since, constructed a concrete masonry dam, of which two views are shown in Figs. 1 and 2. It was designed to withstand substantially 35-feet head at up-stream side, with 12 feet of backwater. It has withstood three floods up to this time, in successive years. It was designed also, with a view to several feet of water flowing over it. Such a wall may be used at Lockport, where solid rock foundations come to the surface of the ground.

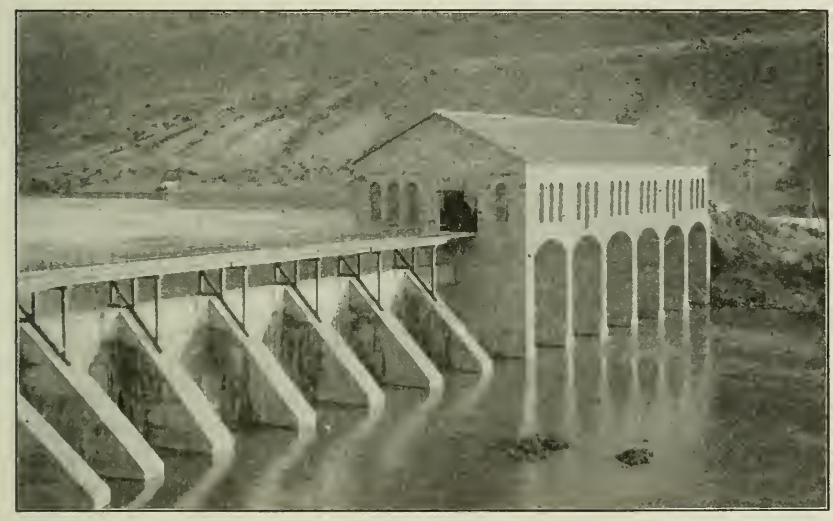


Fig. 1.

The top of this wall would be at substantially –8.00 feet Chicago datum, so that, if any water be flowing which does not go through the power house, it can flow over the whole length of the wall, which is about 15,000 feet. Thus designed, the greatest flood to be anticipated would not raise the water as much as one foot over the top of the wall, and it would hold the head water at substantially the same level at all times. This elevation, –8.00 feet Chicago datum, it will be remembered, is substantially the highest level of head water available for continuous power. Such a wall would be less than 18 feet high down to the wire mill road, thence 18 feet high to near the power house, and at the power house about 27 feet high for a short distance. There would be no construction on the opposite, or west side of the pool above the power house. Such a wall would average three yards to the lineal foot throughout its whole length, and should not cost more than $300,000, the masonry being everywhere three feet thick. In that Idaho dam it was five feet thick, but the load was much heavier.

Instead of a wall, however, suppose that an embankment be made on the same location, except adjacent to the power house, where the wall should be retained. The top of the embankment may be given an elevation of –5.00 feet, Chicago datum. If such a construction be made, a spillway of concrete masonry about 600 feet long should be made, say at the Wire Mill road, as indicated on the map. The cost of such construction, utilizing the existing bank east of "tail race" between the Bear Trap dam and the Wire Mill road, will be somewhat less, and should not exceed $250,000. The Sanitary District plans provide for using this same bank, but raising it to a height of ten feet higher, or to +5.00., Chicago datum. Their specification for construction may be used. The crest of the spillway being short, it should be fitted with flash boards for use at low water, which would be but a small expense, to be merged into operating expenses.

Whether a wall or embankment be adopted, overflows should be provided adjacent to the power house, as indicated on the map, in order to clear floating ice and drift. The cost would not exceed $25,000 for an elaborate arrangement, and is included in the figures already given.

The conditions below the power house are worthy of note. Note the deep excavation made by the Sanitary District, extending north from Ruby street as indicated on the map. Also, note the wide spread of the river at low water (as indicated by the hatching) northward from said excavation to the site of the power house. It has been stated that hereinbefore that the available head under a design of the kind being described could not exceed 29 feet, as against 27 feet available under a design which excluded the use of flood waters and confined the water for power purposes to that which may flow in the Drainage Canal. Now, if the slope between the site of the proposed power house and the site of the Economy Plant be allowed to be 2½ feet (6 inches of slope being allowed in the head race), then little or no work will, in the opinion of the writer, be needed below the site of the power house. Certainly $50,000 would cover any needed expenditure, and this would be in the immediate vicinity of the power house in order to clear the water easily from the wheel bays. Any backwater effect due to flood waters in the tail race will be of no consequence on the amount of power, because at such times there will be plenty of water to develop the power with diminished head, enough water wheel capacity only being needful for this purpose, and this at small expense, not exceeding $25,000.

It appears that the expense of hydraulic development sums up between $300,000 and $350,000, except the cost of power house, mechanical installation, and the work needed at the Lockport and wire mill highways. At Lockport road, the existing highway bridge will not be disturbed, and the approaching embankment at the west end only will have to be raised. At the wire mill road a new bridge will be needed with approaches in embankment. The cost at those highways should not exceed $25,000.

The power house expense, including its contained machinery, will be common, to all designs for developing the water power in question, except as to water wheels as already stated, and need not be discussed. The other expense, as already estimated, sums up between $350,000 and $400,000.

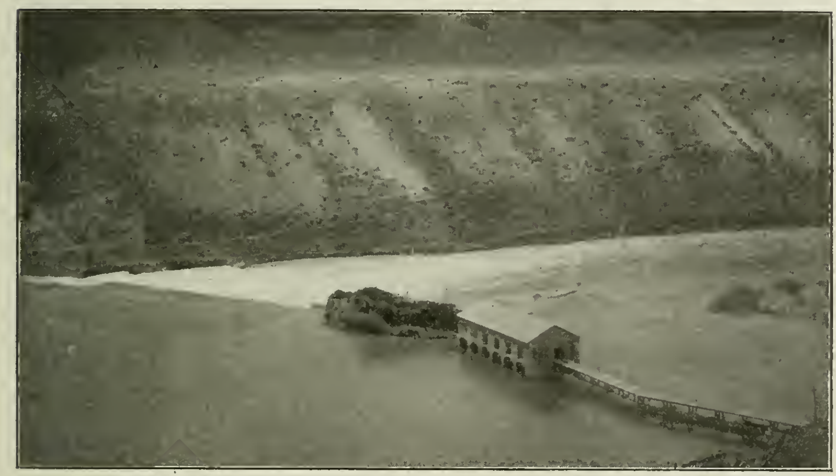


Fig. 2.

It has already been stated that until that time when the flow in the Drainage Canal is made 600,000 cubic feet per minute, and during which time the slope in the Drainage Canal will be less, and the available head possibly four feet more than has been considered for the flow of 600,000 cubic feet per minute, that some provision should be made to utilize the increased head. The only way to accomplish this will be to raise the level of the top of the wall or embankment above the power house by four feet. This would increase the cost of the wall design 30 per cent or $90,000 and the cost of the embankment design 20 per cent, or $50,000, thus making the total cost of hydraulic development come between $400,000 and $490,000, according as an embankment or masonry wall be adopted, unless, as in the Sanitary District design, it be contemplated that the maximum level of water above power house site comes substantially level with top of the earth embankment, in which event the embankment plan would cost only $360,000.

Among the advantages of the plan proposed may be cited the fact that, when the Drainage Canal is extended as a navigable channel to and through Joliet (and the proposed plan is on a site where such a waterway would doubtless never be considered), flowing water would be kept out of a channel between high embankments, so that the velocity met by boats would be little or nothing, and the danger of boats hitting the walls of the narrow channel and breaking them, would be eliminated.

Again, better advantage can be taken of the maximum possible head available, if flood waters be not used, either in developing more power, or in reducing the cost of installation.

Again, the depth of water against walls or banks confining them is reduced to a minimum, which is in favor of safety, especially considering the occupation of the region just below, viz : the city of Joliet.

Again, advantage is taken of the regulating works of the Drainage Canal as a safe guard, in case of power house accident or otherwise.

Again, the time required for installation is reduced to a minimum, thus saving much in interest on investment during construction.

Again, and all important, the cost of development is reduced to a figure which will lead to a commercial utility justifying the construction.

By way of contrast it may be interesting to note the location and arrangement of the Sanitary District design shown on the map, which will cost, in the writer's opinion, about $2,500,000 to $3,000;000 as against $350,000 to $400,000 for the proposed plan, which would accomplish identically the same result.

DISCUSSION—OCT. 21, 1903.

Mr. Isham Randolph, M. W. S. E.—On Monday morning I received through the mails a printed paper entitled "Hydro-Electric Power Development at and Near Joliet, Ill., Using Chicago Drainage Canal Water," by Thos. T. Johnston, C. E. I should have refrained from discussing this paper had it been a criticism of me personally, for I should rightly judge that if more than twenty years spent in close touch with this honored organization had not earned respect and confidence, I would have lived and worked with you in vain.

The criticism however, falls upon a great public work for which I stand sponsor and in defense of which I accept any gauntlet that may be thrown down. The onward march of this great work has been stayed for some years because of lack of legal authority to proceed. The last General Assembly of the State of Illinois enacted a law which made it possible for active operations to be resumed, and for a clear understanding of the conditions of that resumption, I will state that this law provides for three things: The annexation of territory to the existing Sanitary District, namely, 78 6-10 square miles on the North, known as the "North Shore District," and 94 5-10 square miles on the South, known as the "Calumet District;" the construction of two channels which will drain these respective districts and carry their sewage into the Sanitary Canal; and the development of water power in the vicinity of Joliet. This law permits the cutting through and abolition of the existing Illinois & Michigan Canal between the upper basin at Joliet and Chicago, as soon as the Sanitary District shall have provided access by means of channels and a lock to be built by it—free of all cost to the State of Illinois or the Illinois & Michigan Canal—which would maintain navigation between said upper basin and the Chicago River. You must know that neither the City of Chicago nor the Sanitary District can be a law unto itself; each when it seeks to do aught which is not provided for in existing statutes, must go, a supplicant, to the State of Illinois, personated by its Senate and House of Representatives. This joint tribunal, known as the General Assembly, is guardian of the interests of the whole people, and every time the Sanitary District has asked privileges of that Assembly, a tribute has been demanded for the people, and right wisely, too, has this been done, for that tribute is one which will redound to the good of Chicago, of the whole state; and not that alone, but the Nation will participate in the boon that is conveyed in the possession of a great navigable channel. This navigable channel is completed as far as the Controlling Works at Lockport, and contracts have now been awarded which will carry it on four miles further to meet the

Waterway which the United States will, sooner or later, build through to the Mississippi. Now, bear in mind, that we, who have been vested with the responsibility of carrying on this great work, have always had at heart three cardinal purposes: 1st, Sanitation, Chicago's health first and foremost; 2d, Navigation; 3d, Water Power. And our effort is to bring about a harmonious consummation of these great objects. Is this wisdom or foolishness?

Now for the paper. Its pages are illumined with a discussion of water power, water power only, as a text for adverse criticism. The writer stands with me upon one platform, that is, opposition to the transmission of this great power to Chicago; after that we have nothing in common. In what I am about to say I voice no one but myself. I commit no one but myself, I speak not as an official, I speak as a citizen. The Sanitary District of Chicago owns, between Robey Street, Chicago, and Hickory Creek, Joliet, about 7,000 acres of land; more than five thousand of these acres might, under proper conditions, be income bearing; today they are as unprofitable as the arid sands of the desert. The mission of this great power which we are about to create, is properly to turn the wheels of industry in factories located upon our own lands, alongside our own channel. Where in this broad land are there greater inducements for the establishment of great industrial enterprises? The finest artificial waterway man has ever built, invites the deep sunk keels of the great carriers of the Great Lakes to plow its ample flood. On either side and easy of access are the steel laid tracks of transcontinental lines; crossing it at intervals are railways which girdle the Great Metropolis of the West and make the interchange between all the railroads which bring it prosperity and wealth. Add to this cheap power in its most convenient form and you have pictured the manufacturers' paradise. Had I the settlement of this great question, I would make the dedication now to industrial enterprises along this "man-made river," and the West would see its own Lowell before half a decade should have come and gone. Our writer enters into a labored and elaborate effort to show that this water power will not pay as a commercial proposition. I have had no time to compile figures which I believe would show the utter fallacy of his arguments, but I ask the thoughtful men here present if they believe that a large block of water power which can be developed on an outlay of $100 per net horse power within thirty-five miles of the heart of Chicago, located as this power is, would prove an *uncommercial* venture? If this be true, how visionary and wild must be the men who are harnessing Niagara Falls at a cost of about $180 per horse power with the avowed purpose of transmitting their power to industries located 75 miles away.

Now the writer claims to have worked out the hydraulic determinations from which the probable flow lines in the Sanitary Channel were arrived at, and so he did. On page 309, he fixes the ultimate water level at the Controlling Works as —8. I believe this is on the assumption of a zero lake level. If I am wrong, I will accept correction. Speaking with the wisdom derived from flow measurements and observations taken in the effort to determine accurately the ultimate outcome, the height at the Controlling Works when the lake is at datum and the channel is carrying 600,000 cubic feet per minute, will be something less than 3 feet below datum. These computations have been worked out by that careful and competent hydraulicean, Ernest L. Cooley. Had the scientist who determined for us our hydraulic slopes and grades been able to predetermine these facts, a different grade line would have been established and a trifle of 1,731,600 cubic yards of solid rock excavation would have been saved, besides a few hundred thousand cubic yards of glacial drift.

At the time that Mr. Johnston made these computations he undoubtedly worked upon the best data which he could obtain going to show the efficiency of large channels, but there was no data available giving results in such a channel as was then to be built and he did the best he could, probably as well as any other man would have done, in reaching his conclusions. The fact that the actual demonstration of efficiency in the completed channel is much greater than his work led him, and us who relied upon that work, to expect, is not a valid cause for charging him with error in his work.

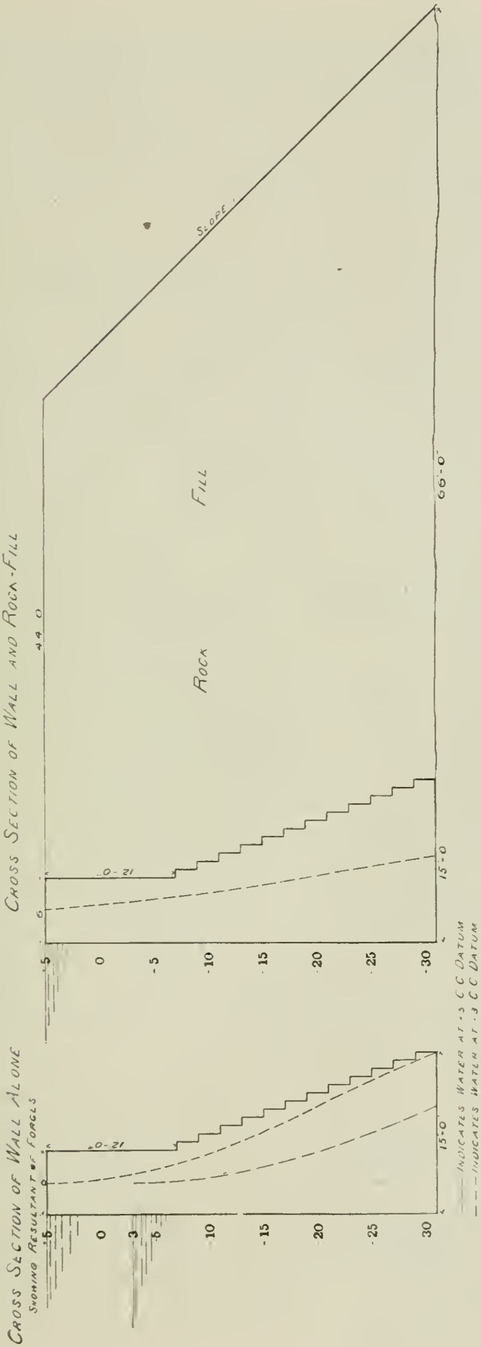
But in the light of present plans this excess excavation is not wholly lost, for the cutting of the Calumet-Sag Canal will bring in about 225,000 cubic feet which the rock channel must care for in addition to the 600,000 cubic feet for which it was originally designed.

This added volume, be it remembered, will add nearly 9,000 horse power to the potentiality of the water power we are discussing without adding a dollar to the cost of the channel-ways we are now providing, and the capital account will be swelled by only the cost of the hydraulic and electrical machinery necessary to generate the increased power, say $250,000, and our unit cost would then be about $83.33 per horse power, including the cost of three miles of navigable channel.

Mr. A. S. Crane, Prin. Asst. Engineer of the Sanitary District, has revised my figures and finds that we will have an available head of 34 feet, with a flow of 600,000 cubic feet per minute, as against 32 feet, upon which I have based all my estimates of power. The writer gives some very optimistic figures and a project for a different development of this power from that which is to be built. All that I can say is that the map which I now exhibit illustrates a modified form of the same project ending three-fourths of a mile North of the site he has selected in his project and developing a head of fourteen (14) feet only. This map bears this inscription: "Approved by Isham Randolph, Chief Engineer. Designed by Thos. T. Johnston, Asst. Chief Engineer. Structural details by W. T. Keating, Asst. Engineer. Constructed by——" In 1897, bids were received on this project after advertising 60 days, upon specifications which I have with me. As a result, the lowest bid was for the masonry and embankment, $392,347.48. For the Wier dam, $129,660.00. Total, $522,007.48, and with wheel pits, power house and machinery yet to be heard from. The contrast of prices for labor and material then and now is interesting. Attacks have been made in the public press on the stability of the the retaining walls on the east side of the channel about to be built. These walls will be built of native cement concrete, faced and coped with three inches of Portland cement mortar. I exhibit a cross-section of this wall as planned, which Mr. Crane has prepared for my use, showing where the oblique resultant intersects the base for different depths of water. Taking the unbacked wall shown on the left, the resultant shown by the dotted line, for the ordinary stage of water (—3), cuts the base line at a point between the middle and outer third. With the water at + 5, top of wall, the resultant shown by broken line, cuts the base at the outer edge of the masonry. He has also prepared for me a cross-sectional diagram showing the wall backed up with broken stone and showing the resultant for a water height of + 5 intersecting the base line almost at its middle. Will any sane engineer say that this is a dangerous construction or one which carries an incipient menace to life and property in the Valley below? This is nothing more nor less than a rock-filled dam, over the crest of which water will never flow, and the wall is a water-tight facing for it.

The writer stands for water power *per se*, first, last and all the time. The Sanitary District stands, first, for the health of its people—sanitation its highest mission. Second, for navigation; and last, for water power—a wise conservation of a potentiality which its work has created, to the end that the thing created may help to bear the expense of its creation. Gentlemen, I desist, and beg you to charge the infliction of my discussion to *gratuitous engineering advice.*

Mr. G. M. Wisner, M. W. S. E.—This is intended, principally, to be a discussion of that part of Mr. Johnston's paper having to do with the comparative cost of the production of power by an Hydro-electric plant and a steam driven plant as given in his table on page 308 of his paper. The same arguments used in this discussion will


Cross Section of Wall Alone
Showing Resultant of Forces
12-0"
15-0
5
0
-3
-5
-10
-15
-20
-25
-30
—— Indicates Water at +5 C C Datum
— — — Indicates Water at -3 C C Datum
Cross Section of Wall and Rock-Fill
12-0"
15-0
6
44 0
66-0"
Rock
Fill
Slope
5
0
-5
-10
-15
-20
-25
-30

Retaining Wall on East Side of Channel to be built. Concrete Masonry Dam, backed with rock fill.

apply to items 2, 4 and 5 of Mr. Johnston's tables on page 304. I will discuss this table of the comparative cost of power in three ways:

1. Using Mr. Johnston's figures as given on page 304.

2. Using these same figures with a combined efficiency of water wheels and generators of 75 per cent instead of 70 per cent as used by Mr. Johnston.

3. A comparative cost based upon 75 per cent efficiency and my estimate of cost of operation.

1. Taking up the question of the sale of the water power to the city for use in pumping stations and for street lighting, I have never understood that any one has seriously considered the sale of the power to the city for pumping purposes. This would necessitate an almost entire change in the pumping machinery and, as Mr. Johnston states, the service is apt to be interrupted. Whether the trustees of the Sanitary District will decide it is policy to sell the power to the city for lighting purposes or not I cannot state, but there is this to be said against it, that, with line losses, etc., the District would have about 15 per cent more power to sell at Lockport than if transmitted to Chicago. This phase of the subject will be considered later, but for the time being let us assume, as Mr. Johnston has, that the power is transmitted to Chicago for lighting purposes; also for the present assume all of Mr. Johnston's figures as given in table, page 304, to be correct. He shows with a combined efficiency of 70 per cent, 21,629 H. P. will be available in Chicago for lighting purposes at an annual expense of $474,414.00, which included an item of $218,112.00 ($6.00 per gross H. P.—his estimate of what the power could be sold for undeveloped); while his estimate of annual cost of steam driven plants to produce the same results is $395,508, a difference in favor of steam of $78,906. Certainly a bad showing if the assumptions are correct and no other factor enters into the matter. But the water driven power has only been used during the night time, no use has been considered by Mr. Johnston for the power for the other 12 hours during the day time, when as a rule, power has a larger demand than during the night. The only additional item of expense to produce the power in the water driven plant for the day 12 hours would be a charge under item, "Operation of Plant." $10,000 should cover this. This added to difference above quoted of $78,906 gives practically $89,000 as excess cost over steam driven plant to produce 25,446 H. P. at Lockport for 12 hours day service to be sold for commercial service, or at a cost to the District of only $3.50 per H. P.; certainly a very cheap power. To accomplish the same with the steam driven plant would add $259,548 to the operating expenses and about $25,000 to maintenance, giving a total of $670,046 for steam driven against a total of $484,414 for water driven plant.

It would not seem unreasonable to assume that the power available at Lockport during the day time could be disposed of at $12.50 per H. P. per year within the next ten years, especially when one takes into consideration the growth of the manufacturing industries in this part of the country and the ideal location for a manufacturing concern in the vicinity of Lockport, there being at this point the Santa Fe, Chicago & Alton, and the E. J. & E. railways (the Chicago outer belt line), as well as deep water navigation to the lakes. The power being disposed of at $12.50 would represent a profit of $9 per H. P. on 25,446 H. P., and gives a profit of $229,014 per annum or 8 per cent on $2,860,010 cost assumed by Mr. Johnston, and at the same time furnish power to light the City of Chicago. In addition to the above $229,014 there is also a profit of $218,112 (Mr. Johnston's item 4) plus $64,702 (item 5) which represent an additional profit of 10 per cent or a total on the investment of $2,860,000 ($2,750,000 plus the "going concern charges") of 18 per cent. It thus appears by Mr. Johnston's assumption that there is a profit of 18 per cent.

2. Mr. Johnston states that he does not consider 75 per cent of the gross power in the water column a conservative figure for the net power of the switch board but under conditions similar to the proposed development at Lockport, and that he "has not felt justified in estimating quite as much as 70 per cent combined efficiency of water wheels and generators." As a matter of fact the wheels installed at the "Soo" developed 82 per cent efficiency and the electrical manufacturers are willing to guarantee 96 per cent. From actual tests made upon a 5000 K. W. machine as high as 97.8 per cent efficiency has been obtained. But using 82 per cent for wheels and 96 per cent for generators you have an efficiency of 78.7 per cent. I have therefore concluded that the Sanitary District Engineers are perfectly justified in assuming an efficiency of 75 per cent when the generators are directly connected with the water wheels; and this would allow over 2.5 per cent for exciters.

Below I have prepared a table using Mr. Johnston's assumptions with the exception that I assume that there will be 75 per cent efficiency of combined wheel and generator which would give 27,234 H. P. at switch board, and 85 per cent of this for lighting purposes in Chicago would be 23,166 H. P.

		WATER DRIVEN		STEAM DRIVEN	
1	Interest on Investment..	4 %	$114,400	4 %	$ 64,865
2	Depreciation and Maintenance.......	2 %	57,200	5 %	81,081
3	Operation of Plant..................		20,000	12.00	277,992
4	Rent...............................	6.00	218,112		
5	Going concern...............		64,702		
6	Miscellaneous.......................				
7	Sinking Fund............ ..				
			$474,414		$423,938

This shows a difference (or excesss of annual cost of water driven machinery) of $50,476 net H. P. available for 12 hours during the day time with an increase of only $10,000 in expense or cost. Reasoning as in the previous case, the power for 12 hours service would cost $2.22 per year. When sold at $12.50 there would be a profit of $10.28 per H. P. or a total of $329,171 per year or about 11.6 per cent on investment and as items 4 and 5 are really a gain, as stated above, there is a total profit of over 21 per cent. This surely is a fairly good business venture.

3. Below I give a table comparing water driven power with steam power based upon the latest practice in and about Chicago. There has been a large steam turbine driven plant installed which I am given to understand has cost in the neighborhood of $150 per K. W. or $112.50 per H. P. As this plant has been installed by a private company and represents an investment of several millions it is only natural to suppose that this plant has the latest and most modern improvements. The Missouri Edison Co. of St. Louis, Mo., has within the past year installed a steam driven electric plant consisting of three units of 3,000 K. W. each and two of 1,500 K. W. each—a total of 12,000 K. W. or 16,000 H. P. The total cost of this plant is $2,000,000, or $150 per horse power.

To be conservative however in this comparison, I have used $100 as cost per H. P., including cost of engines, boilers, generators, building, land, etc., although a cheaper plant, as Mr. Johnson has assumed, could be erected but the depreciation and maintenance would undoubtedly be excessive. As stated before, with 25 per cent loss of efficiency in wheels, generators and exciters, and 15 per cent loss in transmission there is available in Chicogo 23,166 H. P. which at $100 would represent an investment of $2,316,000. It would take at least one year to install this plant as a whole, but if put in place gradually (say during a period of ten years) the money would still be non-productive for at least the same length of time. For this reason I have a "going concern charge" of 2 per cent or $46,000, making the total cost of the plant $2,362,000. It might be further said that to gradually install a plant would probably increase the first cost 5 per cent but I will omit this from the calculation. With the above cost the interest at 4 per cent on the investment would be $94,480 annually.

In water driven plant the interest item is left at $114,400 but it is only proper to say that of this amount about $70,000 should properly be charged against a navigable channel instead of against water power.

For depreciation, insurance and miscellaneous, I have taken 5 per cent of steam driven plant or $115,830 annually. A smaller per cent would provide for depreciation (or a sinking fund), but past experience has shown that in this age of progress and improvements power plants soon become obsolete. For this reason I have, as stated, assumed 5 per cent, which also covers any miscellaneous expense and the item of insurance.

In the water driven plant there will be practically no depreciation except upon the moving parts. I have taken 7 per cent depreciation upon generator and 2 per cent upon water wheels. The estimated cost of generators is $216,000 and of the wheels $110,000. There will therefore be an annual charge of $16,900 for depreciation.

The depreciation on the concrete walls will be so small that it is practically nil. The life of the embankment, which is a stone embankment with an earth and concrete core, will be a great number of years, so that any depreciation on this item can be neglected. On the cut through the solid rock there can be no depreciation. It might be claimed that this cut would fill from the sedimentation but as above this proposed channel the current will be much slower in the wider channel from Willow Springs to Summit and in the Lockport windage basin than in the proposed channel there will probably be very little, if any, sediment left to settle in this new channel. Anyway this item is amply provided for under maintenance, should any dredging be required to maintain the channel. For maintenance I have used for steam driven plant a charge of $2.50 per H. P. per year for 12-hour service, or $57,915 annually. Prof. Chas. E. Emery makes this charge $2.544 for a triple compound condensing engine.

The maintenance for a water driven plant I have taken at one-half that of the steam driven plant or $1.25 per H. P. per year or $34, 067 annually, which is a very liberal allowance.

The cost of operating large electric plants in Chicago—in actual operation—exclusive of interest, depreciation, etc., costs from $30 to $42 per H. P. per year. Prof. Emery gives the cost for a large unit of a triple compound condensing engine at about $15 per H. P. per year for a 12 hour service. The cost of pumping at the 14th Street Pumping Station is about $75 per H. P. per year. I have taken the cost at $15 per H. P. per year for a 12 hour service or $347,490 annually, which is certainly not excessive when one takes into consideration that the price of coal is increasing.

For water driven plant $20,000, Mr. Johnson's figure is used for operation for 12 hour service.

The Sanitary District was offered $4 per actual H. P. after having advertised for bids, and I shall use this as the value or rent of the undeveloped power instead of $6 as assumed by Mr. Johnston. This makes the rent item $145,408; and the "going concern charge" $51,962. As the sinking fund is provided for as depreciation it is not to be considered..

	12 HOUR SERVICE	WATER DRIVEN		STEAM DRIVEN	
1	Interest on Investment	4 %	$114,400	4 %	$ 94,480
2	Depreciation, Insurance, etc.		16,900	5 %	115,830
3	Maintenance and Repairs	1.25	34,067	2.50	57,915
4	Operation		20,000	15.00	347,490
5	Rent	4.00	145,408		None
6	Going concern charge		51,962		
			$382,737		$615,715

The above table shows a balance in favor of water driven machinery of $232,975 annually in addition to items 5 and 6, and there remains 27,254 net H. P. which is available for 12 hour day service at Lockport. In the above discussion Mr. Johnston's estimated amount of H. P. has been used, but upon estimates of the Sanitary District there will be available at least 29,000 efficient H. P. at Lockport based upon a 75 per cent efficiency of wheels and generators. With 29,000 efficient H. P. at Lockport the showing is still more favorable for a water driven plant.

In these days of municipal ownership it would not be public policy to sell the power at $4 per actual H. P. (undeveloped) to a private concern, especially when it is undoubtedly worth more and ought to be easily disposed of at $25 per H. P. (developed) per year for commercial purposes at or near the power plant. This use as stated before would save a line loss of 15 per cent and expense of a transmission line to chicago and at the same time it would increase the value of the District's land in the vicinity of the power house. This increase in value should be credited to the power development. It ought not to be a difficult matter to lease all of this power within five years. So assume that the "going concern charges" are offset by the increase in the value of the District's land and that the power can be disposed at $25 per H. P., and as a matter of fact $30 can probably be obtained for a large per cent of it. It has been found practicable for a large power plant to sell 25 per cent more power for commercial uses than the actual net power, on account of the power not all being in use at the same time. But assume only 20 per cent and the District will have 35,000 H. P. which at $25 would give a gross income of $875,000. For cost of production take items 1, 2 and 3 of last table and $35,000 operating expenses and you have a cost of $200,000 annually which would leave a net income of $675,000 or a profit of about 23 per cent on the investment of $2,860,000 after having allowed 4 per cent to pay interest on construction cost.

Mr. Johnston assumes that power *must* be sold at Chicago for commercial uses, thus losing 15 per cent of the power through line loss, etc. There is no doubt in my mind that with a cheap power, a market can be created within five miles of the power house. I do not agree with him that 5 per cent interest should be charged, as it would be possible to sell 4 per cent bonds above par to build this work. In his commercial use table he has used 3 per cent for depreciation which is entirely too high, as shown in discussing his table on page 308. Assume that the undeveloped power is sold to a private corporation, would the City of Chicago or tax payers be benefitted by the $30,000 item of taxes which Mr. Johnston has charged against the cost of construction? It seems to me that the taxes would be lost to the taxpayers of the Sanitary District and go to the people of Will county in which county the power plant is located.

In conclusion, I wish to emphasize that the proposed Sanitary District development will net over 23 per cent with a flow of 600,000 cubic feet per minute and that the navigable features of this great work have been preserved, giving deep water navigation from Joliet to the Lakes; while under Mr. Johnston's scheme the navigable features are sacrificed, he creating instead a large pool, part of which is practically stagnant thus producing a public nuisance.

It is also known that it is entirely feasible for the canal after completion to carry over 800,000 cubic feet per minute and it is the intention of the Sanitary District to produce this flow. From all indications this will probably be accomplished within the next ten years. This will add about 33 per cent to the available power without materially increasing the cost of this development. With this amount of water flowing and the power judiciously leased the the investment will show a net return of over 33 per cent. It may be said in criticism of this discussion that I have taken a "rosy view" of this power development, but it must be remembered when one speaks of developing steam power for $24 or even $30 per H. P. per year for operating expenses and $70 per H. P. for installation, when the construction of similar plants are actually costing from $112.50 to $150, that that is a very "rosy view."

JOHN FINDLEY WALLACE,

The Chief Engineer of the Panama Canal—Past President, Western Society of Engineers.

From every notable enterprise there arises a great opportunity, and fortunate is the man whose industry, ability and high purpose have fitted him to meet the occasion. Such a man is John Findley Wallace, whom President Roosevelt has selected for chief engineer of the Panama Canal. Ever since Congress authorized the undertaking, speculation has been rife in engineering circles as to who would be selected to take active charge of the work. The selection has been made on the basis of Mr. Wallace's wide experience in engineering, executive and administrative positions, his genius for accomplishment, and also, it is said, his freedom from political influences.

The salary of $25,000 a year may seem quite a remarkable one, but even at that salary Mr. Wallace was for a considerable time unwilling to accept the position. It is probable that a sense of public duty, and the pleasure such a man has in the carrying out of a great work, were the strongest factors in bringing about his acceptance. He has given out no public statement in regard to the matter, other than a brief summary of the task in these words:

"The construction of the Panama Canal involves problems covering the entire field of civil engineering. There are two big harbors to construct at Colon and Panama; extensive surveys to be made to determine which of the five plans proposed is the most economical and commercially advantageous; and extensive borings to determine the cost of locks and dams. Great works must be constructed with a view to controlling the Chagres river, which rises from twenty to to sixty feet sometimes in the course of twenty-four hours, and which follows the route of the canal for twenty miles. Immense reservoirs must be constructed in the mountains to provide water supply for the upper reaches of the canal, to furnish power for lighting it with electricity throughout its length, and supply water to the large cities. There are many other problems of almost equal magnitude."

Although born in Fall River, Mass., the west claims Mr. Wallace, as, when but a small child he was brought to Monmouth, Ill., by his father, who founded Monmouth College. It was in this school that Mr. Wallace received his education for the engineering profession.

In 1869 he started as rodman in the service of the Carthage & Quincy Railroad. Following this, in 1871, he was made assistant engineer in the United States Engineering Corps at Rock Island, Ill. This post, which he held for five years, had chiefly to do with surveys and construction in improvement of Rock Island rapids. It was while in this service that he had charge of the work of excavating the channel through the "Chain-of-Rocks" at St. Louis, using machinery that he had designed and built. This was his first notable achievement. He located and constructed the Peoria & Farmington Railroad, of which he was made chief engineer in 1879, but which he opened as its superintendent. His success with this road led to his being put in charge of the construction of the Iowa Central Railway. This involved the building of a succession of bridges, and when these were finished Mr. Wallace had attained a reputation as a bridge builder of considerable ability.

In 1886 Mr. Wallace undertook a series of surveys for the Union Pacific Railways. Then the Santa Fe Railway selected him as resident engineer. In this way it fell to him to build the substructure of the great Sibley bridge over the Mississippi river at Sibley, Mo., in 1887.

Chicago secured Mr. Wallace for a citizen when the Santa Fe, in 1889, shifted his headquarters to this city. Some time later, while associated with Mr. E. L. Corthell, he had charge of the construction of the joint terminal of the A., T. & S. F. Ry. and Sioux City line of the Illinois Central Railroad, in Chicago.

With the planning of the World's Fair, of 1893, the directors of the Illinois Central were confronted with the problem of handling the greatly increased passenger traffic which the exhibition would bring into Chicago. Mr. Wallace was recognized as the man for the occasion, and the system which he planned and developed won him another laurel in the shape of the position of Chief Engineer of the Illinois Central Railroad. His next task was to solve the problem of a direct line west for his road. This he did in a way that brought great financial returns to the road. For the past three years Mr. Wallace has been General Manager of the Illinois Central Railroad, and during this time he has also made a good record as Chairman of the advisory board on joint track elevation in the city of Chicago.

Although Mr. Stuyvesant Fish, President of the Illinois Central Railroad, had indicated Mr. Wallace as the best man to carry out the plans of the Canal Commission, he was loath to lose his General Manager, and urged him to remain with the road. He argued that Mr. Wallace would soon be receiving a larger salary from the road than that offered by the commission, and that his chances for a long life would be greater if he kept away from Panama.

Mr. Wallace's occupation of his new position entails much of sacrifice and hardship, but the glory of achievement and the sense of a duty fulfilled will more than compensate for these. He was elected a member of the Western Society of Engineers in 1889, and President of this society in 1896. He has also been President of the American Society of Civil Engineers and of the American Railway Engineering and Maintenance of Way Association. M. G.

DINNER TO MR. WALLACE.

On the evening of May 28th, 1904, a complimentary dinner was given to Mr. J. F. Wallace by his engineering friends, under the auspices of the Western Society of Engineers. Some seventy gentlemen gathered in the main parlor of the Auditorium Hotel about seven o'clock for an informal reception, after which they adjourned to the south parlor, where the tables had been set for the occasion.

Mr. Chanute, Past President of this Society, presided, and at his right sat Mr. Wallace, Chief Engineer of the Panama Canal. Mr. Chanute said it was some seventeen years since he was first associated with Mr. Wallace on the Sibley Bridge, and, excepting for a period when they were engaged on widely separated railroads, the intercourse and friendship had been maintained ever since. He congratulated him upon an appointment which placed him in the van of the Engineers of America.

A toast was offered to Mr. Wallace, to which that gentleman responded in his usual pleasant and felicitous manner. He remarked that previous attempts to construct a canal from the Atlantic to the Pacific had not been successful, though it had been the dream of men for many years; that he had every confidence that our country having undertaken the work, it would now be an accomplished fact in the near future; that although it was a trial for him to break away from his associations here, and regardless of all the possible consequences to himself, whether of failure or loss of health, he had accepted the task imposed upon him, and trusted to carry it to a successful issue.

Mr. Chanute then proposed a toast to "The President of the United States," to which Mr. A. W. Sullivan responded. He said he had but just returned from St. Louis in order to have an evening with Mr. Wallace and his friends; that it had been his good fortune to have been associated with Mr. Wallace for the last ten or twelve years, and he could most heartily endorse the action of the President in making such a selection for the Chief Engineer of this great work, in which Mr. Roosevelt was greatly interested; that Mr. Wallace possessed all those varied qualities which make a successful engineer for such work; that he can not and will not fail in the undertaking for which he has been selected, and that doubtless the President of the United States has made a most wise selection of the man to carry out this monumental work.

Mr. Chanute then said it was the good fortune of the Western Society of Engineers to have had the first opportunity to greet Mr. Wallace and to congratulate him upon this recognition as an eminent civil engineer, selected for a notable work; that congratulatory letters had been received from many who could not be present that evening, which were in the hands of Mr. Hotchkiss, Chairman, and in whose favor he would resign his position as toastmaster.

SOME OF THE LETTERS ARE HERE QUOTED.

Mr. Alfred Noble, Past President of this Society, wrote from New York:

"It is with great regret that I have to say I cannot be present at the dinner to Mr. Wallace. If it were possible I would gladly make the journey to Chicago for the sole purpose of joining in the tribute the Society is to pay him in further recognition of his great ability as an engineer and in token of esteem for the man.

"The question as to who should be Chief Engineer of the Panama Canal has naturally been one to which I have given much thought. The man who fills the place adequately will have the greatest responsibility ever placed upon an engineer. The work requires technical ability, but more imperatively requires skill in organization and management, firmness and manliness, moral and physical courage in the highest degree, and sound health. It has long seemed to me that these high requirements could be best met by the appointment of Mr. Wallace, but with this conviction has been coupled a doubt as to whether it would be possible to sever his ties to the great corporation with which he has been so long and honorably connected and which he has served so well.

"As members of the Western Society of Engineers which has been so greatly honored by the selection of one of its members; as members of the engineering profession which will be so greatly strengthened in the eyes of mankind when this task is carried through to a successful issue, and as citizens of the great country hopeful of the added credit to the capacity of its people to perform great works, we have every reason for satisfaction with the wisdom shown in selecting for the most difficult post the man most capable of filling it."

Mr. E. L. Corthell, another Past President of this Society, also wrote from New York:

"Returning last night from a short trip to Europe, I find your invitation to join a number of friends of Mr. J. F. Wallace in a complimentary dinner to be given him previous to his departure for Panama as Chief Engineer of the Interoceanic Canal.

"When, in 1889, pressed with a great variety of important engineering work in the United States and Mexico I needed an associate in whom I could implicitly and fully rely in the work at that time entrusted to me of the Illinois Central and Santa Fe Railway Companies, to build an independent entrance into Chicago, Mr. Wallace was highly recommended to me as just the man I needed. I soon found that he was that man, and from that time until the present his career has been one of continual success and well earned advancement to higher and higher positions of trust and responsibility, until now he is called to perhaps the most important work of the age — to direct the forces that are to unite the Atlantic and Pacific oceans and allow the commerce of the world to flow through the American Isthmus, uniting thus the shores of the continents and especially those of our country.

"I have no doubt whatever, from fifteen years of intimate professional and personal acquaintance and connection with Mr. Wallace, that he will meet all expectations, and while in one sense Chicago is to lose him, the world is to gain him, and we, as members of the Western Society of Engineers, may congratulate ourselves in the fact that one of our number has been called to so great a work and to such a high position of responsibility. Personally, I feel very glad that I was the one who introduced him to Chicago and that from that introduction he opened up the way — always forward — that he by his own skill, eminent ability, and high integrity has traveled from that day to this.

"Therefore, with all my heart I drink to his health with you and to success and still greater honors for him in his arduous and important work."

Mr. Virgil G. Bogue, M. W. S. E., of New York, writes:

"I should be most happy to attend the dinner that is to be given to Mr. Wallace, and regret that I cannot do so. I esteem Mr. Wallace highly, not only for his abilities, but as well for his genial, endearing qualities as a man. In honoring him the society honors itself. The occasion will be one that he will remember, for it will encourage him with the thought that he has friends, and that he goes to his long, hard task with the sympathy and good wishes of his professional brethren."

Mr. J. J. McVean, M. W. S. E., who has been an invalid for a long time, writes from Grand Rapids, Mich.:

"It is with great regret that I am unable, on account of my physical condition, to be present at the dinner to be given in honor of our distinguished friend, Mr. J. F. Wallace. I can only join you in wishing him the greatest success in the undertaking for which he is so fully qualified, and in hoping that he may be spared from any sickness or trouble that will prevent his being able to carry out, to a final conclusion, the great project with which he has been so wisely entrusted."

Mr. Fred. Davis, M. W. S. E., of Newport, Me., writes:

"I regret exceedingly that from this distance I cannot conveniently attend the complimentary dinner to be tendered to Mr. J. F. Wallace, on the occasion of his departure to assume direction of the completion of that most important public work of the age, the Panama Canal.

"I join with the members of the Western Society of Engineers in sincere felicitations to Mr. Wallace upon his appointment, and most heartily hope he may be spared in good health to endure the strain of and to witness the completion of the work that he will contribute so largely towards its ultimate success."

Mr. Geo. W. Kittredge, Chief Engineer C., C., C. & St. L. Ry. Co., writes from Cincinnati:

"I have your invitation to join in giving a complimentary dinner to Mr. J. F. Wallace, prior to his departure from Chicago to assume his duties as Chief Engineer of the Panama Canal.

"My high regard for Mr. Wallace as a man and as an engineer, and my pleasure at his appointment to so honorable a position would urge me to accept, but a previous engagement for that date makes it necessary for me to decline.

"Please extend to Mr. Wallace my most sincere regret at not being able to show my esteem and regard by being present."

Mr. H. G. Prout, Gen'l Mgr. Union Switch & Signal Co., Pittsburg, writes:

"Returning to my desk after an absence of eight days, I find your circular announcing a dinner to Mr. Wallace. I am very sorry indeed that my business engagements are such that I cannot possibly be in Chicago next Saturday night, and have wired you to that effect. Few things would give me more pleasure than to join in this dinner, to renew acquaintance with some of my Chicago friends, and especially to testify by my presence there my high appreciation of Mr. Wallace and my great pleasure in his appointment as Chief Engineer of the Panama Canal."

Many other letters of congratulations and regrets were received from members of the society and friends of Mr. Wallace, but only a few can be here noted: Mr. Lederle, of New Orleans; Mr. Hudson, of Knoxville, Tenn.; Mr. D. C. Jackson, of Madison, Wis.; Messrs. Poetsch and Perrigo, of Milwaukee; Messrs. L. W. Bates and Geo. E. Thomas, of New York; Mr. Salmon, of Buffalo, etc., etc.

Mr. Parkhurst, President W. S. E., responding to the toast, "The Western Society of Engineers," said he had known Mr. Wallace for fifteen years, and that while with us Mr. Wallace had always been leading, guiding and cheering us, and it was our regret that we should lose the presence of such a friend and leader, but that he trusted he would be spared to return to us with well earned rewards for his to-be-distinguished, world-famed work.

Capt. R. W. Hunt, M. W. S. E., responding on behalf of the "American Society of Civil Engineers," stated that he was only a plain private in that Society, but felt honored when called upon to represent it, and also to pay a tribute to the worth of the guest of the evening. He also stated that some years ago, when the Am. Soc. C. E. held a meeting in England, the guests of the Institution of Civil Engineers, Mr. Wallace as president presided at the meeting in a way which was an honor to the society of which we are fellow members. an honor to the profession, and an honor to our country. The speaker had no anxiety as to the results of the new work to be undertaken by Mr. Wallace, and thought the President of the United States did well in making such a wise selection, giving us renewed confidence in the wisdom of the Chief Executive of the nation. Capt. Hunt also stated that Mr. Wallace possessed great qualities as an engineer and as an executive officer, and was undoubtedly the man for the place, which would involve great trials and calls for the highest qualities of the man. In closing, he wished him health, happiness and the success which will follow his work.

Mr. Wallace has been closely identified with the work of the "American Railway Engineering and Maintenance of Way Association," in which many other members of this Society are interested, and it was most natural that a toast to that association should be responded to by the president, Mr. Hunter McDonald, of Nashville, Tenn., as follows:

"*Gentlemen* — My summons to this gathering did not convey the information that I would be expected to express for the members of the American Railway Engineering and Maintenance of Way Association the regret we all feel at the prospect of parting with our first president, the distinguished gentleman in whose honor we are assembled here this evening.

"Saying good-bye to friends is always unpleasant. To say it for 450 others ought logically to multiply the unpleasantness, but with the unanimity of sentiment which I know to exist among our members, and the encouragement offered by this occasion, it becomes a mere matter of oratory. Careful search among our membership for several years past has developed the melancholy fact that we have but one orator; and it is still more melancholy to reflect that we are shortly to lose even him.

"We feel that we owe our existence as an organization to the energy and wisdom of our beloved Wallace. There were others who supplied the raw material, but to the sculpture of his unerring judgment is due the organization as it stands today. He it was who chartered the vessel, selected the crew, trained the officers, gave the good ship a sailing chart, and with sealed orders started it on its voyage But he did not leave us entirely to our own devices. By a system of wireless telegraphy, peculiarly his own, he has kept in touch with our navigators and often warned them from dangerous waters. Our voyage is by no means near its end, and it is easy to understand our regret at the prospect of his being removed beyond the effective zone of his wireless impulses.

"But we can comfort ourselves with the thought that the great enterprise which he has been called to take charge of will be the means of shortening the journey of many other mariners. The Society under whose auspices we are assembled this evening, has taken a fitting step toward letting our country know how fortunate it is in being able to command the services of one of its own citizens who is so eminently qualified to assume the direction of the most important undertaking in the commercial history of the world. His selection is a guarantee that the work will be executed with freedom from scandal and political incompetency, so far as intelligence, energy and integrity, combined in the executive head of the enterprise, can do so. Our profession at large should spare no pains to bring our countrymen to the fullest realization of their good fortune and of the sacrifices he makes in order to serve them.

"In behalf of the membership of the American Railway Engineering and Maintenance of Way Association, I extend to our honored guest our heartiest good wishes for success in his new field of usefulness and our sincere regrets at having to part with him. We hope it will not be for always, and that the old desire which seems to lurk within the hearts of all men who have once had a taste of railroading will, upon the completion of his steamboating experience, prompt him to turn his face again toward his first love. Our lights will be kept burning in hopeful anticipation of his triumphant return, when the boys will give him the glad hand and try to find him another job."

Other responses to the sentiments of the evening were made by Dr. Harper, of the University of Chicago, who spoke on behalf of "Chicago and the Men of the West;" Mr. Delano, General Manager of the C., B. & Q. R. R., who spoke for "The Railroads;" Mr. Isham Randolph, who has long been Chief Engineer of our own "Drainage Canal;" Mr. B. J. Arnold, President "American Institute of Electrical Engineers," who spoke on behalf of that society and the science which it represents, which will be an important agent in this grand work; Mr. Archibald MacArthur, who represents that important class of workers, the successful contractor on heavy construction work; Mr. J. T. Harahan, Vice-President of the Illinois Central Railroad Co., who has been closely associated with Mr. Wallace for fourteen years, paid a high tribute to Mr. Wallace as an engineer and executive officer, who had been instrumental in raising the Illinois Central R. R. from a "scrap heap" to its present superb physical condition; Mr. H. M. Wilson, who spoke for the Railways and the "Technical Press, and their regard for Mr. Wallace and his new work;" Mr. S. F. Andrews, General Attorney for the I. C. R. R., who spoke on behalf of "The Law," but added a just tribute to the guest of the evening as a friend. Short speeches from other men all bore testimony as to the regard and esteem felt toward our guest, Mr. J. F. WALLACE.

W.

INTERNATIONAL ENGINEERING CONGRESS.

St. Louis, Mo., October 3-8, 1904.

Under the Auspices of the American Society of Civil Engineers.

CIRCULAR No. 3.

Circular No. 1, Preliminary Announcement, was printed in JOURNAL Feb., 1904, page 91, and Circular No. 2 was printed in JOURNAL April, 1904, page 212.

The following list gives the names of engineers who, by special invitation of the Committee in Charge, have promised to review the development of engineering practice in their respective countries during the past ten years, on the subjects under which their names are printed.

Owing to the fact that publications of the Congress as indicated in this list will cost more than Membership Fee, it is necessary to increase the cost of Membership in the Congress.

Notice is hereby given that Membership Fees mailed on or before July 1st, 1904, will be received at original rate of $5. Between that date and October 1st, 1904, the Membership Fee will be $10.

Communications relating to the Congress should be addressed to the undersigned.

CHAS. WARREN HUNT,
Secretary of Committee.

220 West 57th Street,
New York, May 25th, 1904.

PAPERS PROMISED.

HARBORS.—*Subject No 1:*

W. MATTHEWS, C. M. G., M Inst. C. E., Chief Engr. of Dover Harbor, England.
V. E. TIMONOFF, M. Am. Soc. C. E., St. Petersburg, Russia
H. WORTMAN, Engr., Royal Corps of Waterstaat, Amsterdam, The Netherlands.
BARON E. T. QUINETTE DE ROCHEMONT, M. Am. Soc. C. E., Inspecteur General des Ponts et Chaussees, Professeur, a l'Ecole des Ponts et Chaussees, France.

ON THE GREAT LAKES.

DAN C. KINGMAN, Maj., Corps of Engrs., U. S. A.
D. D. GAILLARD, Capt., Corps of Engrs., U. S. A.

ON THE SEA COAST.

CASSIUS E. GILLETTE, Capt.. Corps of Engrs., U. S. A.
CHARLES H. MCKINSTRY; M. Am. Soc. C. E., Capt., Corps of Engrs., U. S. A.

NATURAL WATERWAYS.—*Subject No. 2:*

JAMES L. LUSK, M. Am. Soc. C. E., Maj., Corps of Engrs., U. S. A.
K. E. HILGARD, M. AM. Soc. C. E., Zurich, Switzerland.
A. B. MARINKELLE, Engr., Royal Corps of Waterstaat, Utrecht, The Netherlands.
M. CHARGUERAUD, Ingenieur en Chefs des Ponts et Chausees en Chef de la Navigation de la Marne, France.

ARTIFICIAL WATERWAYS.—*Subject No. 3:*

W. L. SIBERT, M. AM. SOC. C. E., Capt., Corps of Engrs., U. S. A.
W. H. HUNTER, M. Inst. C. E., Chief Engr., Manchester Ship Canal, England.
M. DE LINT, Asst. Engr., Royal Corps of Waterstaat, Terneuzen, The Netherlands.
J. NELEMANS, Engr., Royal Corps of Waterstaat, Terneuzen, The Netherlands.
L. F. E. VAN HOOGENHUYZE, Asst. Engr.,Royal Corps of Waterstaat, Terneuzen, The Netherlands.
M. CHARGUERAUD, Ingenieur en Chef des Ponts et Chaussees, Ingenieur en Chef de la Navigation de la Marne, France.

Lighthouses and Other Aids to Navigation.—*Subject No. 4:*

D. W. Lockwood, Lieut.-Col., Corps of Engrs., U. S. A.

Thomas Matthews, M. Inst. C. E., Chief Engr., Trinity House, London, England.

Luis Luiggi, Director General, Obras del Puerto Militar, Buenos Aires Argentine Republic.

C. Ribiere, Ingenieur en Chef des Ponts et Chaussees, Ingenieur en Chef du Service Central des Phares et Balises, France.

Traffic on Improved Waterways, Etc.—*Subject No. 5:*

* Edward P. North, M Am. Soc. C. E., New York City.

Purification of Water.—*Subject No. 6:*

a. For Domestic Use.

*Allen Hazen, M. Am. Soc. C. E., New York City.

M. Bechmann, Ingenieur en Chef des Ponts et Chaussees, Ingenieur en Chef du Service des Eaux et del l'Assainissement de la Ville de Paris, France.

b. For the Production of Steam.

James O. Handy, Chief Chemist, Pittsburg Testing Laboratory, Pittsburg, Pa.

Turbines and Water Wheels.—*Subject No. 7:*

Gardner S. Williams, M. Am. Soc. C. E., Ithaca, N. Y.

P. O. Levy Salvador, Ingenieur des Constructions civiles, Ingenieur au Ministere de l'Agriculture, France.

Irrigation.—*Subject No. 8:*

Elwood Mead, M. Am. Soc. C. E., Chief, Irrigation Investigations, Washington, D. C.

* Sir Hanbury Brown, K. C. M. G., M. Inst. C. E., Late Chief Inspector of Irrigation, Lower Egypt.

J. E Meijier, formerly Director of Indian Public Works, The Hague, The Netherlands.

P. O. Levy Salvador, Ingenieur des Constructions civiles, Ingenieur au Ministere de l'Agriculture, France.

Railroad Terminals.—*Subject No. 9:*

Elmer L. Corthell, M. Am. Soc. C. E., New York City.

W. T. Foxlee, M. Inst. C. E., London, England.

Ernest Pontzen, Cor. M. Am. Soc. C. E., Ingenieur des Constructions civiles, France.

Underground Railways..—*Subject No. 10:*

William Barclay Parsons, M. Am. Soc. C. E., Chief Engr., Rapid Transit Comm., New York City.

Basil Mott, M. Inst. C. E., and David Hay, M. Inst. C. E., Central London and City and South London Railways, England.

M. Biette, Ingenieur des Ponts et Chaussees, adjoint a l'Ingenieur en Chef du Chemin de fer Metropolitan de Paris, France.

Locomotives and Other Rolling Stock.—*Subject No. 11:*

William Forsyth, M. Am. Soc. M. E., Chicago. Ill.

G. J. Churchward, M. Inst. C. E., Chief Locomotive Supt., Great Western Ry., England.

Edouard Sauvage, Ingenieur en Chef des Mines, Professeur a l'Ecole des Mines, France.

Live Loads for Railroad Bridges.—*Subject No. 12:*

*Henry W. Hodge, M. Am. Soc. C. E., New York City.

The Substitution of Electricity for Steam as a Motive Power.—*Subject No 13:*

James G. White, M. Am. Soc. C. E., New York City.

Alexander Siemens, M. Inst. C. E., London, England.

Sewage Disposal.—*Subject No. 14:*

* George W. Fuller, Assoc. M. Am. Soc. C. E., New York City.

M. Bechmann, Ingenieur en Chef des Ponts et Chaussees, Ingenieur en Chef du Service des Eaux et de l'Assainissement de la Ville de Paris, France.

DISPOSAL OF MUNICIPAL REFUSE.—*Subject No. 15:*
    RUDOLPH HERING, M. Am. Soc. C. E., New York City.
    M BOREUX, Inspecteur General des Ponts et Chaussees, Chef du Service de la Voie publique et de l'Eclairage de la Ville de Paris, France.
VENTILATION OF TUNNELS.—*Subject No. 16:*
    *CHARLES S. CHURCHILL, M. Am. Soc. C. E., Chief Engr., Norfolk & Western R. R., Roanoke, Va.
    FRANCIS FOX, M. Inst. C. E., London, England.
HIGHWAY CONSTRUCTION.—*Subject No. 17:*
    JAMES OWEN, M. Am. Soc. C. E., Newark, N. J.
    WILLIAM E. MCCLINTOCK, M. Am. Soc. C. E., Chairman, Massachusetts Highway Comm., Boston, Mass.
    G. FORESTIER, Inspecteur General des Ponts et Chaussees, Ancien Professeur a l'Ecole des Ponts et Chaussees, France.
CONCRETE AND CONCRETE-STEEL.—*Subject No. 18:*
    EDWIN THACHER, M. Am. Soc. C. E., New York City.
    JOHN S. SEWALL, Capt., Corps of Engrs., U. S. A.
    FR. VON EMPERGER, Vienna, Austria.
    ARMAND CONSIDERE, Inspecteur General des Ponts et Chaussees, France.
DEEP FOUNDATIONS.—*Subject No. 19:*
    JOHN F. O ROURKE, M. Am. Soc. C. E., New York City.
    W. F. DRUYVESTEYN, Engr., Royal Corps of Waterstaat, Groningen, The Netherlands.
    LOUIS COISEAU, Vice-Pres. de la Societe des Ingenieurs Civils de France, Entrepreneur de Travaux Publics, France.
THE MANUFACTURE OF STEEL.—*Subject No. 20:*
    WILLIAM METCALF, Past-Pres., Am. Soc. C. E., Pittsburg, Pa., and CHAS. B. DUDLEY, M. Am. Soc. C. E., Altoona, Pa.
TESTS OF MATERIALS OF CONSTRUCTION.—*Subject No. 21:*
    E. L. CANDLOT, Ingenieur Civil, France.
  STEEL.
    *WILLIAM R. WEBSTER, M. Am. Soc. C. E., Philadelphia, Pa.
    L. L. BACLE, Ingenieur Civil, France.
  TIMBER.
    GAETANO LANZA, M. Am. Soc. M. E., Boston, Mass.
  CEMENT.
    WILLIAM A. Aiken, M. Am. Soc. C. E., Pittsburg, Pa.
PASSENGER ELEVATORS.—*Subject No. 22:*
    THOMAS E. BROWN, M. Am. Soc. C. E., New York City.
PUMPING MACHINERY.—*Subject No 23:*
    IRVING H REYNOLDS, M. Am. Soc. M. E., Youngstown, Ohio.
    WILLIAM MAYO VENABLE, Assoc. M. Am. Soc C. E., New Orleans, La.
DREDGES: THEIR CONSTRUCTION AND PERFORMANCE.—*Subject No. 24:*
    A W. ROBINSON, M. Am. Soc. C. E., Montreal, Canada.
    F. B. MALTBY, M. Am. Soc. C. E., Memphis, Tenn.
    J. C. SANFORD, Maj., Corps of Engrs., U. S. A.
    J. HERSENT, Ingenieur Civil, Entrepreneur de Travaux Publics, France.
STEAM TURBINES.—*Subject No. 25:*
    FRANCIS HODGKINSON, M. Am. Soc. M. E., Pittsburg, Pa.
    M. RATEAU, Ingenieur des Mines, Professeur a l'Ecole des Mines, France.
ELECTRICAL POWER—GENERATING STATIONS AND TRANSMISSION.—*Subject No. 26:*
    L. B. STILLWELL, M. Am. Soc. C. E., New York City.
NAVAL ARCHITECTURE.—*Subject No. 27:*
    W. L. CAPPS, Rear-Admiral, Chief Constructor, U. S. N.
    Sir WILLIAM H. WHITE, K. C. B., F. R. S., Pres., Inst. C. E., late Director of Naval Construction, England.
MARINE ENGINEERING.—*Subject No. 28:*
    W. F. DURAND, M. Am. Soc. M. E., Ithaca, N. Y.
    M. DAYMARD, Ingenieur en Chef, Conseil de la Compagnie Generale Transatlantique, France.

Dry Docks.—*Subject No. 29:*

M. T. Endicott, M. Am. Soc. C. E., Rear-Admiral, Chief of Bureau of Yards and Docks, U. S. N.

Cuthbert A. Brereton, M. Inst. C. E., England.

Luis Luiggi, Director General, Obras del Puerto Militar, Buenos Aires Argentine Republic.

Paul Joly, Inspecteur General des Ponts et Chaussees, France.

Ordnance.—*Subject No. 30:*

Thales L. Ames, Capt., Ordnance Dept., U. S. A.

H. C. L. Holden, Lieut.-Col., R. A., F. R. S., Supt. of Royal Gun Factory, Woolwich, England.

George W. Burr, Capt., Ordnance Dept., U. S. A.

Odus C. Horney, Capt., Ordnance Dept., U. S. A.

John T. Thompson, Capt., Ordnance Dept., U. S. A.

Fortifications.—*Subject No. 31:*

S. W. Roessler, Maj., Corps of Engrs., U. S. A.

George W. Goethals, Maj., Corps of Engrs., U. S. A.

Mining Engineering.—*Subject No. 32:*

E. G. Spilsbury, M. Am. Soc. C. E., Trenton, N. J.

Edouard Gruner, Ingenieur Civil des Mines, France.

Engineering Education.—*Subject No. 33:*

Robert Fletcher, Assoc. Am. Soc. C. E., Prof. of Civil Engineering, Dartmouth Coll., Hanover, N. H.

Calvin M. Woodward, Dean of Eng. School, Washington Univ., St. Louis, Mo.

W. Cawthorne Unwin, F. R. S., M. Inst. C. E., Cooper's Hill College and City and Guilds Technical College, London, England.

* Surveying.—*Subject No. 35:*

Officers of the United States Geological Survey.

Officers of the United States Coast and Geodetic Survey.

Wharves and Piers.—*Subject No. 37:*

John A. Bensel.—M. Am. Soc. C. E., Engr. in Chief, Dept. of Docks and Ferries, New York City.

The Manufacture of Cement.—*Subject No. 38:*

Robert W. Lesley, Assoc. Am. Soc. C. E., Philadelphia, Pa.

* Advance papers of those marked * are on file in the library W. S. E., and can be consulted by those interested.

Joint Meeting of the Institution of Mechanical Engineers and the American Society of Mechanical Engineers.

AT CHICAGO,

MAY 31st to JUNE 3d, 1904.

An interesting and important event in the engineering circles of Chicago and in the international relations of engineers, was the joint meeting of the Institution of Mechanical Engineers (Great Britain) and the American Society of Mechanical Engineers, which was held in Chicago on May 31st and June 1st to 3d. Nearly one hundred members of the British Society were present, including members from France, Belgium, Turkey, etc. The American Society had a large attendance, among which the Chicago membership was well represented. As the meeting partook of a social as well as of a technical character, a large number of ladies and other guests were in attendance, and the total list of members, guests and visitors who registered at the headquarters (in the Auditorium Hotel) was very nearly one thousand. The meeting was an outcome of the St. Louis Exposition, the representatives of the British Society being on a tour of the country, with the Exposition as their principal objective point.

At the business sessions of the meetings, the presidents and secretaries of the two societies sat together on the platform, and each president assumed the chairmanship while the papers by members of his own society were under consideration. Papers by home and foreign engineers were presented indiscriminately and the American and foreign engineers participated equally in the discussions, so the meeting was assentially an international convention of mechanical engineers. The two presidents were Mr. J. H. Wicksteed, of Leeds, England, and Mr. Ambrose Swasey, of Cleveland, O.

The first session was held on the evening of May 31st, when the City Comptroller, Mr. L. E. McGann, as representing the Mayor, delivered an address of welcome. This was followed by brief addresses by the presidents of the two societies, and the meeting then adjourned to give place to an informal reception and social gathering in the parlors of the Auditorium Hotel.

The technical part of the proceedings opened with a general discussion on the question of labor and wages, in the course of which there was some very plain talk as to the deficiencies of both employers and employees in their mutual relations on both sides of the water. The disposal of garbage by cremation was the next subject, but here the British engineers had the floor, although if American municipal engineers had been present, much interesting information might have been given as to American experience in this direction.

The steam turbine next came in for a large share of attention, but here the Americans were mostly in evidence, except that a paper by Prof. Rateau (of Paris) was presented. Some of the points brought out were that the economic performances of various steam turbines do not vary greatly from each other ; that a high degree of superheat is not economical when economy of cost is to be considered ; that the steam turbine is more economical in performance than the reciprocating engine ; that the condensing equipment is often unnecessarily elaborate, and that the present designs will probably develop into improved standard designs of machines within the next decade.

The subject of power plants of tall office buildings naturally again kept the Americans to the front, as buildings of this class are comparatively rare abroad, and the elaborate power plants of these buildings are distinctively representative of American mechanical engineering enterprise.

The subject of electric and hydraulic cranes for dock work, however, claimed the consideration of the British engineers again. The author of the paper had used both types of cranes and favored the electric, but the two principal discussions strongly supported the hydraulic cranes, although it was admitted that many of these are not as efficient and convenient in service as they might and should be.

Other subjects dealt with by papers and discussions included : The use of superheated steam in compound engines ; tests of gas engines ; the effects of strain and of annealing upon alloys ; the composition and strength of cast iron, and the measurement of work done by machine tools.

The final subject was that of testing the efficiency and performance of locomotives. There was very little discussion, owing to lack of time, but the papers included road tests, and the use of locomotive testing plants in this country and in England.

The excursions and technical visits included the following trips :

1. The Illinois Tunnel Company's tunnels for telephone and freight transportation service.

2. The same company's automatic telephone exchange.

3. The South Chicago works of the Illinois Steel Co.
4. The Stock Yards and Packing Houses.
5. The Drainage Canal.
6. The clearing yards of the Chicago Terminal Transfer Co.
7. The Fisk Street power station (with steam turbines) of the Commonwealth Electric Co.

The two principal social events were a reception by the officers of the two societies and a concert. The reception was held at the Art Institute, giving the visitors an opportunity to see the collections of painting, statuary, and other art treasures. The concert (by the celebrated Thomas Orchestra) was given in the Auditorium, and was a very brilliant affair, attended by over six hundred persons. This was the closing event of a most successful international meeting of engineers, and the climax of the friendly relations was reached when, at the conclusion, the entire audience rose and, to the same tune (the national air of both Great Britain and the United States) sang, first, "God Save the King," and then "My Country, 'tis of Thee." T.

American Institute of Electrical Engineers—High-Tension Transmission Convention in Chicago, June 21-22.

High-tension transmission was the general subject taken up at a convention of the American Institute of Electrical Engineers held in Chicago on June 21st and 22d, and with a good attendance and hearty interest in the work the result of the meeting was highly satisfactory.

The convention was held in the rooms of the Western Society of Engineers in the Monadnock Building, and Bion J. Arnold, President of the Institute, presided at each of the sessions. The number in attendance the first day was 85, while a few more were registered on the succeeding day.

Prominent among those present were President Arnold; the Secretary of the the Institute, Mr. Ralph W. Pope, of New York; Dr. F. A. C. Perrine, of Pittsfield, Mass.; Messrs. R. D. Mershon, and F. O. Blackwell, of New York; Charles F. Scott, of Pittsburg; P. Junkersfeld, of Chicago; H. B. Alverson, of Buffalo, and W. B. Jackson, of Madison, Wis., all of whom, and many others, participated in the discussions of the various papers presented at the convention.

Two sessions were held on the 21st, at which five of the papers upon the program were read. These papers showed careful preparation on the part of the authors, and brought up many questions of general interest to those connected with high-tension transmission work.

The papers with their authors were as follows:

"Line Construction with Steel Supporting Structures and Long Spans," by F. O. Blackwell, of New York.

"Protection of Cables from Arcs Due to Failure of Adjacent Cables," by W. G. Carlton, of Chicago.

"The Use of Ground Shields in Transformers," by John S. Peck of Pittsburg.

"Conditions for Continuous Service over Lines Operated in Parallel," by M. H. Gerry, of Helena, Mont.

"Protection of High-tension Lines Against Static Disturbances," by H. C. Wirt, of Schenectady, N. Y.

On June 22d the remaining paper on the program—"Synchronous Motors for the Regulation of Power-factor and Line Voltage," by B. G. Lamme, of Pittsburg, was read, and also the report of the transmission committee on data collected, which were opened for general discussion along with the papers of the preceding day.

A pleasant break in the routine work of the convention was a trip through a part of the Illinois Tunnel Company's system on the afternoon of the second day. After lunch the party assembled at the society rooms, and from there went to the the entrance to the tunnels on Fifth avenue, where they were taken down into the network of subterranean passages which now underly the streets of Chicago, and were given a short trip on electric cars 40 feet below the surface of the streets.

After this experience a short session was held for further discussion, when the meeting was adjourned. and the members were entertained at the Chicago Yacht Club for dinner, through the generosity of the Chicago Edison Company, the General Electric Company, the Westinghouse Electric & Manufacturing Company, the Western Electric Company, the Arnold Electric Power Station Company, and Sargent & Lundy.

After dinner, through the courtesy of Captain Darby, of the U. S. S. Dorothea, the party was taken for a short cruise on Lake Michigan, and it was with reluctance that order to disembark was obeyed. Captain Darby was not present in person, but his place was admirably filled by Commander King, who personally looked after the welfare of his guests. H. W. Y.

Armour Institute of Technology.

The eighth annual commencement of the College of Engineering of Armour Institute of Technology was held on the evening of Wednesday, June 16th, 1904, at Armour Chapel.

A most interesting and masterly address was delivered to the graduates by Senator Jonathan P. Dolliver, of Iowa.

At the request of President Gunsaulus a report of the attendance for the academic year 1903-1904 was read, showing a total enrollment of 1,589 students. Of this number 496 were enrolled in the College of Engineering, 345 in the Scientific Academy, 575 in the Evening Classes, and 174 in the Summer Courses.

The degree of Bachelor of Science was conferred on thirty-three graduates of the different departments of Engineering as follows:

Fifteen of the Electrical Engineering Department; ten of the Mechanical Engineering Department; five of the Civil Engineering Department; two of the Chemical Engineering Department, and one of the course in Architecture.

Engineering degrees were granted to the following graduates of Armour Institute of Technology:

Ralph H. Rice, B. S. (E. E.) '97,
Edward W. Leeper, B. S. (E. E.) '98,
Louis I. Porter, B. S. (E. E.) '99,
receiving the degree of Electrical Engineer.

Clarence L. Tarbell, B. S. (M. E.) '99,
the degree of Mechanical Engineer.

Alfred S. Alschuler, B. S. (in Architecture) '99,
the degree of Master of Science.

In conferring the degree of Doctor of Science on John Findley Wallace, Chief Engineer of the Panama Canal, President Gunsaulus spoke as follows:

"In recognition of distinguished services performed as officer of one of the most important highways of American commerce, eminent wisdom as the adviser of his fellows in undertaking and prosecuting vast private and public enterprises involving scholarly intelligence and high technical ability, mature and valuable guidance to others of his profession who have heard or read his words, especially now when he so worthily enters upon his duties as Chief Engineer of the United States in the construction of the Panama Canal, we, the trustees and faculty of Armour Institute of Technology, recognizing his absence from us to-night as only another evidence of his patriotism and devotion, confer upon John Findley Wallace the degree of Doctor of Science, with all the rights and dignities thereof."

H. M. R.

The Case School of Applied Science.

The occasion of the inauguration of Charles Sumner Howe, as President of the Case School of Applied Science, Cleveland, Ohio, on the 10th and 11th of May, was, to the delegate from the Western Society of Engineers, a very enjoyable season, especially from the fact of meeting so large a number of gentlemen connected not only with the higher education of engineers, but with higher education in the broadest sense.

The two days of the function, beginning with the reception at the University Club the evening of the 10th, followed by exercises of varying character and terminating in the banquet the evening of the 11th, are fairly well set forth in the memorandum and specifications filed with this report, which contain also the names of the representatives of the various institutions and societies present. Your delegate had nothing to do except to look wise and listen to the discourses. As a result of "research," the conclusion is, in his mind, that the ambition of the educator is human—that is, to drive the fastest machine—and that *quality* of "research" rather than quantity is sought. In attempting to express this the law of the lever is useful. The composite idea of the advanced educators seems to be that, having the privilege of bestowing 1,000 units of "research," and "broad and deep culture," it is more to the credit of any given institution to work these 1,000 units into one man, rather than to place one unit in each of 1,000 men.

Your delegate had previously supposed that the presidents and professors of the advanced institutions were different from the balance of the human family. However, stories were told from the platform antedating Rameses I., and the orator introduced himself as though he had taken part in the affair, and from this you can understand how your delegate felt himself entirely at home. It is, however, very satisfactory to call the attention of an engineering society to the fact that of the various presentations from the platform, there was heard more commendation by the educators, of the remarks of the one practicing engineer (Mr. Freeman, discussing "education") than of the many addresses of the instructors.

H. E. Horton.

The "Memorandum and Specifications" filed with the above report include a programme of exercises at the inauguration of President Howe, with a list of the delegates representing various institutions and societies. In this extended list is to be noted the Massachusetts Institute of Technology by its President, Dr. Pritchett; Yale University, Sheffield School, by Prof. Richards; University of Pennsylvania, by Prof. Doolittle; Columbia University, by Dean Hutton; University of Tennessee, by President Dabney; the United States Military Academy, by Brig. Gen. Garretson; University of Michigan, by President Angel; University of Wisconsin, by President Van Hise; University of Illinois, by Dean Ricker; University of California, by President Wheeler; Purdue University, by President Stone; Rose Polytechnic Institute, by President Mees; University of Cincinnati by President Ayres; Northwestern University, by President James; Iowa State College, by President Storms; Ohio State University, by President Thompson; Johns Hopkins University, by President Remsen, etc., etc. Many scientific and engineering societies and associations were also represented.

In the inauguration exercises, addresses were delivered, "On behalf of the universities" by President Remsen of Johns Hopkins; "On behalf of the technical schools" by President Pritchett of the Massachusetts Institute of Technology; "On behalf of the technical societies" by Mr. J. R. Freeman, of the Am. Soc. C. E. and the Am. Soc. M. E.; and "On behalf of the colleges of Ohio," by President Thwing of the Western Reserve University, etc., etc.

The Inaugural Address was from President Howe, "Does a Technical Course Educate?"

These inaugural ceremonies cannot be fully described in the space available, but that same evening there was a banquet, in the menu of which the fancy of some apt mind made humorous use of the familiar form of "Engineering Specifications," substituting however appropriate terms and names. The toasts under the heading of "Proposals" carried out the same idea under the sub-titles of Grading, Foundations, Decoration, Ventilation, Efficiency Test, etc., etc. The (mis)quotations, coupled with names listed to reply to these toasts, as President Dabney of Tennessee, President Wheeler of California, President Gunsaulus of "Armour," President Van Hise of Wisconsin, and Mayor Johnson, would indicate that the treatment of these (technical?) subjects was in a light and entertaining vein and provocative of mirth and good fellowship. W.

BOOK NOTES.

Telephony. Arthur Vaughan Abbott, C. E., McGraw Publishing Company, New York, 1903. Cloth, 6x8½ inches. 6 vols. $1.50 per volume, or set for $6.00. 4 vols. ready.

When parts 5 and 6 have been issued, this work will be one of the largest dealing exclusively with telephone engineering.

The author, coming to telephony after a considerable experience in the longer established and therefore perhaps more exact branches of engineering, has collected a very large amount of information concerning the various ways in which telephonic things have been done. His work is of much value as a compendium of various methods, and in some instances one might even wish the explanations wery fuller in order that the disadvantages might be more apparent. A greater fullness would also be valuable in the chapter on definitions, for the reason that telephone is old enough to have created a nomenclature of its own, containing words which do not exist in other arts; and, still more mystifying to the novice, many words which have other meanings in other arts. It is regretted that some of the definitions which are given in the work are so framed that unless read in the light of previous knowledge a wrong conception will be given.

The six sections are to cover the following phases:

Part 1. The location of the central office;
Part 2. The construction of underground conduits;
Part 3. The cable plant;
Part 4. Open wire lines;
Part 5. The substation;
Part 6. Switchboards and the central office.

A chapter of the first volume is devoted to a mathematical proof of the axiom that more wire is required to enable one subscriber in a system to talk privately with any one of the remainder, if he has a direct line to each, even if each subscriber had a line and all of them centered in an office for intercommunication, unless the number of subscribers in the exchange is smaller than three.

The chapters upon determining the most economical location of central offices should be found of much value to those having occasion to make development studies for telephone exchange construction. Even a cursory reading of these chapters will show the ordinarily unappreciated importance of making the proper locations, because of the effect not alone on investments, but upon operating expense year by year.

In the volume on aerial lines are contained some notes upon the effect of Pupin coils in telephone lines, reproducing the results of certain tests in Germany, and it is stated that in a general way the investigation showed that the insertion of balancing inductances extends the distances of possible transmission about fivefold; this result is reached because of the ability of distributed inductance to counteract the harmful effect of the distributed capacity. One might wish, however, that the author gave Dr. Pupin a freer measure of praise for what he has done.

In the volumes dealing with actual construction, perhaps the most valuable portions for general use are those providing forms of specifications and contracts. It is conceivable that with the assistance of these volumes a work might be planned, bids secured, and contracts let without the assistance of an engineer.

As to what the succeeding volumes may contain we are, of course, in doubt, except as we may form an opinion from what matter has appeared in periodicals. It is to be regretted that the scope of the work as covered by the titles of the volumes does not include a treatment of operating methods, as it is probable that the more important telephone economies are results of ways of doings things rather than of the implements for doing them.

It is to be hoped that the volume on central office equipment will treat in an exhaustive manner the present problem concerning manual and automatic switching equipments.

Measured by investment, the telephone is now third in the list of electrical industries. Measured by rate of increase it is first. The time has come when engineers of other arts need to know something of it, and this is one of the few works which attempt to treat the whole subject. S. G. McM.

Coal is King. By M. C. Huyette, Marquette Building, Chicago. Cloth, 6 x 9 inches; pp. 104; 4 color plates, maps and charts. Regan Printing House, Chicago. Price, $5.00.

Although the author remarks that the material in this book is boiled down, there is yet a considerable portion which is unadvisable in such a work, notably the newspaper clippings which tend to confuse, though presumably intended to be impressive. To our mind, the plates illustrating impurities of coal are misleading. In effect, the author states that coals containing these impurities should be avoided, instead of making a discrimination on the basis of cost per unit power.

The coals illustrated, except in the extreme case of that represented in Plate 4, are usable. The film of calcite, which the author calls "calcium," is not in itself objectionable, except that it is inert in the fire. However, should it carry a little pyrites of iron, as shown in Plate 4, it is objectionable. The condemnation of coal "showing white on the cars," due to a calcite coating, would mean that 40,000,000 tons in Illinois, and half as much more in the adjoining states, would not be mined each year. It goes without saying that with equal prices, it is to everyone's interest to use the best coal obtainable at a given cost, per unit of power.

The Atchison, Topeka & Santa Fe Railroad, running from Chicago to California, uses Illinois Third Vein Coal as far as the Mississippi River, then through Missouri, it uses a grade not quite so good, Missouri coal; through Kansas, it uses coal from Pittsburg, Kansas, a very good coal, but one which would be scorned in the orginal Pittsburg region. In Colorado, it uses Trinidad (Colorado) coal, which is a higher grade than the Kansas product, although it has a considerable amount of ash. This is a coking coal first obtainable at this point. In the northern part of New Mexico, New Mexico coal is used, of the same grade as the Colorado. At Albuquerque it suddenly changes to a lignite coal, a considerable part of which blows out the stack. Oil burning engines are used from Arizona to the coast. This is an example of a road able to haul its own coal, yet changing grades from place to place, because it is cheaper to use fuel at hand than to haul it long distances.

In the chapter, "Cost of Power," the writer touches the keynote of the whole matter, which may be summarized by the statement that the final test is the cost of evaporating water, and that the comparison between coals should be made on the basis of total cost of evaporating a certain number of pounds of water "from and at 212 deg. Fah."

The compilation of chemical analyses to show the relative values of Illinois coals, taken largely from the University of Illinois bulletins, is interesting, but in the case of coals with which we are familiar, we know certainly that there is no basis in fact for the wide variation in analytical results given for coals from adjoining states. We do not doubt the accuracy of the analyses, but it is the old question of misleading sampling. The compilation of power tests indicates considerable advantage in the use of automatic stokers over hand-firing, which should be expected.

The map of the coal fields of the United States is interesting, but the great Rocky Mountain Region is credited merely with areas of lignite and coal fuels, whereas it possesses also large fields of high grade coking and steam coals, and a little anthracite.

The statement that coal operators should crush and screen the coal into uniform sizes at the mines might be good advice for those in the coking coal region, but not for operators in western fields, for there the great amount of slack resulting from the crushing process could not be utilized in coke making and would have to be sold at a nominal price. Moreover, it would be exposing a greater number of "faces" of the crushed coal to deterioration, as western coals do not "stock" or "weather." Such coal should be crushed only where used and just before using.

G. S. R.

Principles of City Land Values. Richard M. Hurd, President, The Lawyer's Mortgage Insurance Co. The Record and Guide, New York, 1903. 8vo, cloth, pp. 159. 147 illustrations.

One might look a long while before finding a book which at first glance seems to deal with an out-of-the-way and unique subject, yet which enunciates principles and information of such practical importance, not only to the municipal engineer but to the practical business man and investor.

"The Principles of City Land Values," deals with an interesting subject from every standpoint. Our information about such matters, when we have any, is largely built up from practical experience and generally is vague and unreliable even then. The engineer who has watched the growth of large cities and has planned for their care and development, has an unusual opportunity to study the principles of their growth and accretion in land value.

Seldom however does he go into the theory of the thing so thoroughly and carefully as is done in the work before us. In its perusal he will find many vague and ill defined phenomena which he has failed personally to reason out, carefully analyzed and reduced to concrete definition in a way which will both interest and delight him.

The principles of the location of cities and the topographical and defensive reasons which influenced their beginnings, are first noted and illustrated by examples.

The reasons for their growth and the study of its character and direction is further undertaken, and finally the values of city lands are discussed and analyzed, and the economic laws which control their increase or cause their decline fully inquired into.

Numerous examples are given in maps and plates as to the land values of the principal cities of this country. The cost and character of buildings by which lands are improved, are carefully considered from an investment standpoint.

The book does not deal in theories. No allusions are made to the unearned increment or the ethical questions involved in the values of city property, but it merely undertakes to state the facts as the author finds them, without complaint or protest, and reasons from such facts to the cause and effect.

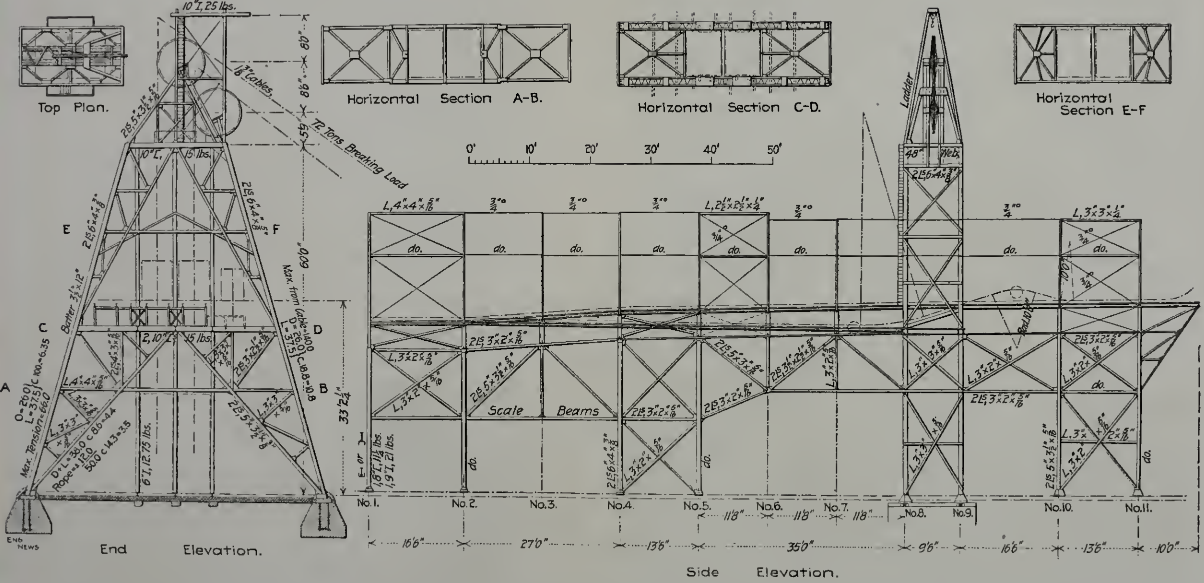
The book is very interestingly illustrated, and should be read by every engineer having to do with municipal progress, as well as those in the engineering profession desiring to know more of the scientific principles which are the basis of real estate investments. ·

J. W. A.

Western Society of Engineers

Vol. IX. No. 4. Aug., 1904

Rice—Use of Steel for Coal Mine Tipples.



STEEL FRAME WORK OF TIPPLE FOR CARDIFF NO. 2.

Courtesy of Engineering News Pub. Co.

Journal of the
Western Society of Engineers.

VOL. IX. AUGUST, 1904. NO. 4.

THE USE OF STEEL FOR COAL MINE TIPPLES, AND A CLASSIFICATION OF SAME.

George S. Rice, M. W. S. E.

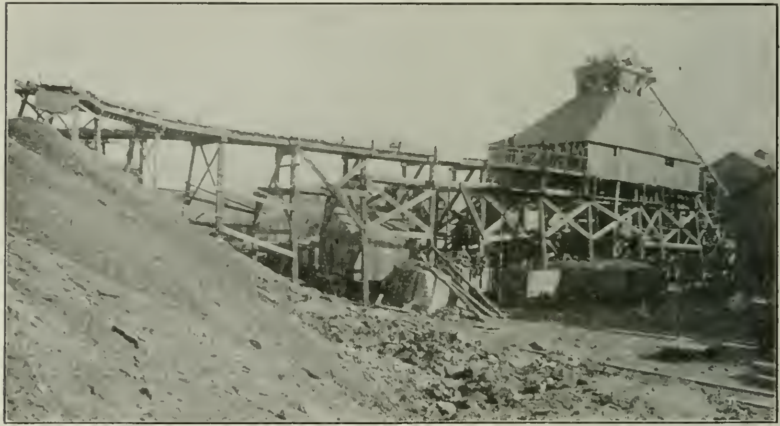
Read May 11, 1904.

As recently as ten years ago structural steel was almost unused in building mine shaft towers or head frames in this country. Abroad its use had been somewhat extensive on account of the comparative scarcity of lumber. But here, with the exception of a very few coal tipples in Pennsylvania, and a few head frames in the Michigan copper country, there were practically no structures of this kind constructed of steel.

As the writer's practice of late years has chiefly been in the development of coal mine properties of the west, he will discuss from that standpoint the various questions relating to coal tipples. The latter term, as properly used, includes both the "tipple" proper or dumping part of the structure as well as the "head frame" or "tower" immediately over the shaft and supporting the hoisting-rope sheaves.

Up to the time mentioned, about ten years ago, steel had not been seriously considered by western coal operators for several reasons. It was expensive as compared with wood, both on account of the structure itself, and on account of good foundations required. Tipples built of wood frequently have neither brick nor stone foundations and are supported merely on wood blocks. Further, it was thought that steel would not be durable, exposed as such structures are to powder smoke from the mine, and frequently to sulphurous gases from nearby burning "dirt" dumps on the surface. Then at that time, stationary screens were used and the strains the tipple was subjected to were light and easily taken care of by ordinary wood framing. Finally the attention of the various structural building concerns had not been directed to this business.

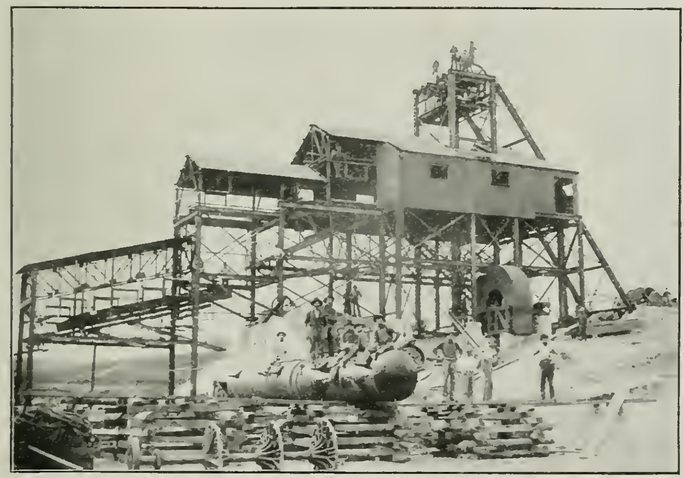
About the time mentioned, the Spring Valley Coal Company, of Illinois, had a serious fire. Their No. 1 shaft tipple burned and the brands falling into the shaft set fire to the curbing of the shaft and adjacent entries. The shaft caved in, and the company was put to heavy expense to sink another and to recover the mine. They concluded to put up a steel tipple and be safe from possible repetition of this loss. The tipple was designed and built by Pittsburg (Pa.) parties and was, the writer thinks, the first steel coal mine tipple built west of Pennsylvania. About the same time there began to be a demand in some of the markets for better screened coal than furnished by the straight bar screens then in use. Some of the companies experimented successfully with the use of shaking screens, and this improvement received a decided impetus a year or two later in Illinois, from the agreement forced on the operators by the miners requiring payment to be made on the basis of run-of-mine coal, instead of on the basis of "screened lump" over a certain specified bar screen.



KEB MINE, IOWA.—TIPPLE OF ILLINOIS & IOWA FUEL COMPANY.
Example of substantial wood construction; side hoist; flat floor; stationary bar-screens; dirt trestle at left.

The strains set up by a long shaking screen 30 to 50 feet long are out of all proportion to the amount of power required to drive the screen particularly with the more or less clumsy and unbalanced screens first used. Shaking screens are now usually divided into sections of as nearly equal weight as possible, driven by pairs of eccentrics on the same shafting 180 degrees apart. The weights are not great,—two to three tons for each section empty and as much again when loaded,—but as the screens have a stroke of four, five or six inches, and make respectively 140, 125 or 110 double strokes per minute, according to the design, the pull and thrust at either end of the stroke is considerable. It is chiefly the shifting load of coal that makes it impossible to more than partially balance the pull and thrust of the eccentrics.

The wooden frames first in use, from which the shaking screens were hung, generally proved quite inadequate to transfer the strain to the foundations. The same was true of the first steel frames, for the structural builders did not appreciate the effect of the lively shaking, and in the case of one light steel structure erected in Indiana, the screens are said to have "kicked the legs off the main tower frame" in a very short time. The difficulties that often surround the designing of shaking screen frames are exemplified by the writer's first experience with them about eight years ago at the Ladd Mine in Illinois. Here a stationary bar screen had to be taken out and a shaking screen put in its place. The screens were to extend over three railroad tracks, at a height sufficient to clear railroad coal cars, and also to load cars on a fourth track, with no opportunity for foundations, except for small post piers, nor chance to insert diagonal bracing, except in the space between the first track and the main shaft, a distance of eight feet. The shafting driving the eccentrics was in this case about 20 feet above the ground, so it was manifestly not advisable with only an 8 foot base to use wood, besides which it was necessary to have the frame all up and ready before taking out the bar screens, so it was found advantageous to use long 15-inch I-beams, running through the existing wood structure, from which to hang the screens. Each of the two I-beams was supported by a post at the outer end, and at the inner end each was attached to a triangular frame which carried a boxing for the shafting. These triangular frames were braced together laterally and had substantial though contracted stone foundations. While the above described frames were somewhat elastic, they were efficient



CLEVELAND (IOWA) No. 4—TIPPLE OF WHITEBREAST FUEL CO. OF ILLINOIS.
Example of tipple with side hoist, and flat floor. Coal passes over bar-screen into weigh-hopper (miners paid on lump coal basis), thence all coal passes on to shaking screens for rescreening, and loading on four tracks. This tipple is arranged for a side hill location.

and are still in use, though the old wooden head frame and tipple have since been replaced by steel.

Early in 1898 the writer designed a steel tipple for the Cleveland (Iowa) No. 4 Mine erected the following spring, and which was the first departure from wood in Iowa.* Also a tipple for Cardiff (Illinois) No. 1 shaft was designed about the same time. The latter tipple was the second built of steel in Illinois. Since then, especially in the last two years, steel tipples have multiplied rapidly in Illinois and the adjoining states, not to speak of the large number built in the eastern coal fields. During this period, the companies with which the writer is concerned have built three more of steel.

It is an interesting feature, and at first sight a peculiar one, that none of the five structures built by the companies with which the writer is connected have been duplicates, or in fact resembled one another; nor has this been altogether a process of evolution. The question is frequently asked by structural builders why is there such a lack of standardization, or in fact, anything like uniformity of apparatus in soft coal mining. They say—coal is coal, why can it not be handled in the same kind of mine cars running on tracks of some standard gauge, and why cannot screens be made alike and the coal receive uniform sizing like anthracite? While not defending the present entire lack of system, the writer will point out some of the present obstacles to obtaining uniformity.

First, the great variety of mining conditions met with; for example, in the State of Illinois the veins worked vary from the three foot "Wilmington" or "Third Vein" in the north part of the state, to the nine foot veins in the south part of the state. The former are worked by the "long-wall system;" the thicker veins by the "room-and-pillar system." The roof at one locality may easily be "brushed" —that is, taken down to make head room where necessary, while in another locality it is too hard, or else it is not advisable to brush it, necessitating low pit cars. Some roofs stand better when the "entries" are narrow, requiring narrow pit cars. In other cases the vein lays very hilly, that is, up and down and small cars are required. In general, the effort of the advanced practice of the day is to make the pit cars as large as the local mining conditions permit, up to a capacity of two and one-half (2½) to three and one-half (3½) tons. However, the latter limit is considered debatable. Usually the limit is set by the natural grade of the mine tracks. To generalize, the limit of size in any mine is the largest car that can be pulled out of a room with the steepest normal grade of that mine, by the largest mule that the height of the room road will allow to enter. On the more permanent main roadways, mechanical haulage, either rope or electrical, can take charge of the most difficult conditions that can be found.

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*See illustration on previous page.

It is evident from the foregoing that a uniformity of car bodies cannot be expected throughout such a state as Illinois for instance, but there might be uniformity in each district.

As to the gauge of track, some standardizing might be done to advantage. Pit car gauges run from 26 inches to 42 inches and embrace every size between these limits. With the smaller gauges, up to 34 inches, the practice is to use small wheels fixed to the axles and outside boxes like railroad car trucks, the body of the car over-hanging the wheels. With the wider gauges the car body sets directly on the axles between the wheels, so that larger wheels can be used. The latter usually turn on the axle, and are termed "loose" wheels. The majority of pit cars, particularly the large ones, are of this second type. While it would be a slight advantage to have a standard gauge, this is relatively unimportant in the planning of the tipple structure, as compared with standardizing the size of the cars. But as stated, the latter condition is well nigh impossible to obtain, except in each mining district of uniform mining conditions.

Another feature of the physical characteristics of mines that has an important bearing in the general design of the tipple structure, is whether or not the roof is of such nature that surplus rock must be hoisted and dumped. In the long-wall mines of the north part of the state, for every four or five cars of coal, a car of rock refuse must be hoisted and disposed of. In the thin vein room-and-pillar mines there is much less to hoist, and in the thick veins none at all, since if any is produced, there is ample room to store it below ground.

In the matter of screens the practice is very varied. Some have bar screens only; others, bar screens for lump coal and shaking screens for egg, nut and pea coal. Revolving screens, so much used formerly for this purpose, have generally been discarded. The majority of operators are now putting in shaking screens for all sizes of coal when building new tipples.

As regards the details of the screens, they may be made single deck or double deck, and hung by pendulating rods or mounted on wheels. In this direction standardization would be useful to builders, but its present practicability may be doubted, when taking into account the variety of coals which may be of hard or soft nature. Then the purpose for which the coal is to be used, must be taken into account whether for locomotives, stationary practice, or domestic use; also if it be "stocked" or used immediately. All these have a bearing, so it must be admitted that standardizing in any direction is not as easy as might first appear.

We will now attempt a general classification of tipples, which will apply to those of either wood or steel construction. The greatest difference obtains from the style of cage used. Two general classes are formed by the use in one, of the self-dumping cage, and in the other, of the rigid cage.

A self-dumping cage is one in which the platform of the cage is hinged. The hinge or axle is below the platform; in some it is at the center; in others it is a little off center. The car is held on the platform by clamps of various form. When the cage, in hoisting, nears the point of tipping, a roller on the side of the platform enters a curved channel track which tips the platform and its car, causing the latter to dump its load. At a large majority of the mines in the middle and south part of Illinois and also in Indiana these self-dumpers are used. A subdivision of the self-dumper is the hopper cage, in which the hopper tips in similar fashion to the tipping platform of the self-dumper. Coal is dumped into the hopper, when at the bottom of the mine shaft, either directly from pit cars or, in one example in this state, from self-discharging bins.

BIG MUDDY No. 8. BIG MUDDY MILLING AND MINING COMPANY.
Example of tipple with side hoist for self-dumping cages. Weigh-hopper arranged for dumping on either side of two sets of railroad tracks. Coal screened over shaking screens.

The hopper cage is like the skip of the copper and iron region, and while its mechanical simplicity recommends it, any dumping of soft coal breaks it up more or less, and the use of the hopper cage makes two dumpings, as against one where the pit-car is brought to the top. There is another objection; it cannot be used for hoisting and lowering men, but the former reason is the most weighty one in this part of the country, where the largest percentage of lump coal obtainable is desired. At present there is but one example of the hopper cage in Illinois.

The plain or rigid cages are the older style and while used in most of the very small plants, they are also used in some of the largest and most modern plants. Other things being equal, and provided there is plenty of "elbow room" on the "upper landing," the plain cage allows a larger dumping capacity than the self-dumper. There are several reasons for this. First, the self-dumper does not always dump the coal out of the pit-car thoroughly, particularly if the coal is wet, thus causing a delay until it is cleared out. Second, any delays in shifting railroad cars or in changing the flaps of screens above ground, or delay below ground, from a temporary lack of loaded pit cars at the shaft bottom, stops hoisting. If the mining conditions are such that rock refuse has to be hoisted and dumped, the cage has to dump to the opposite side or else under certain other arrangements, flaps in weigh hopper or chutes must be shifted, causing a slight delay. On the other hand, with the plain cage, if dumping ceases a minute or two, hoisting may still continue, or if hoisting stops from lack of loaded pit cars below, dumping can continue until the supply on the tipple is exhausted. Further, the hoisting of a rock car causes no additional delay. These little savings in time amount to considerable in the course of a day. Moreover, the self-dumper is much more liable to disarrangement, particularly with deep hoists; and pit cars are very apt to jerk loose when the platform tips and to lodge in the chute. Nevertheless, the writer thinks that for shafts not over 300 feet deep, with large pit cars and no refuse rock to hoist, the self-dumper is both cheaper to install and cheaper to operate, and as large a capacity can be obtained as desirable to try for, in any one shaft, viz.: 2200 to 2400 tons per day of eight hours.

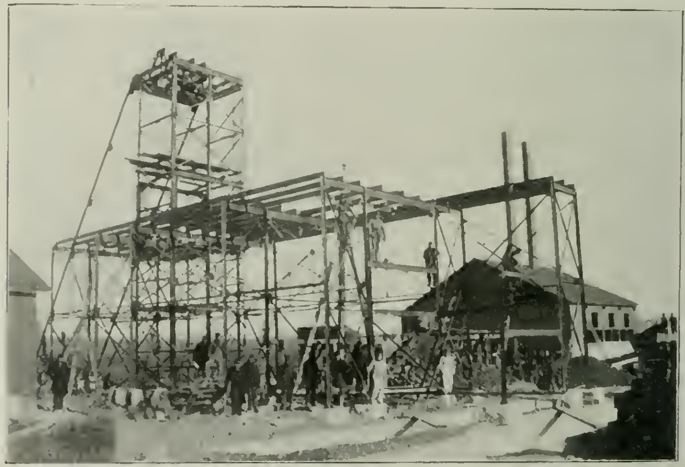
The rigid cages may be classified as follows:

1st, Single Deck,
2d, Double Deck,
3d, Single Deck with two cars side by side,
4th, Single Deck with two cars end to end.

The foregoing are grouped in the order of their capacity for handling coal. The first is the oldest form, and is still the most commonly used of all styles of cages. The second—the double deck cage—is used at only three or four coal mines in the middle west, all in northern Illinois. The third, single deck with two cars side by side, is used abroad more or less. It was figured on for a certain mine near Pittsburg, Kansas, but not installed, and it is not in use anywhere in the west, to the knowledge of the writer. It is certainly very inferior to the fourth plan—single deck with cars end and end. The latter plan is in use at but one mine in northern Illinois, but is now being installed at another plant in the same district.

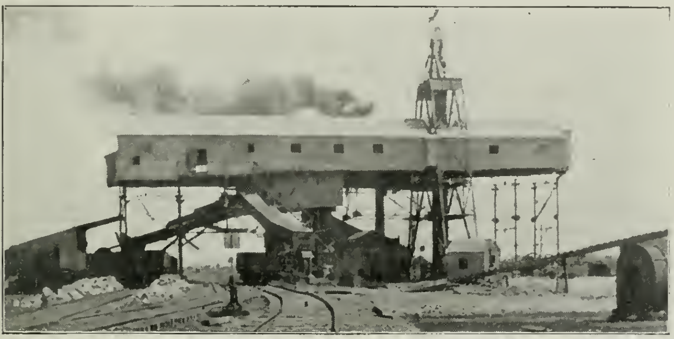
As some members of the society may not be familiar with the details of coal mining, it may be well at this point to explain that, unlike metal mining, coal shafts of any importance are always arranged with two hoisting compartments; the hoisting engines have either one winding drum or, what is the same in effect, two on the same shafting, the cages being hung in balance, so that, when one is at the top the other is below. This is the arrangement, whether rigid cages are used or self-dumpers.

The arrangements for receiving and dumping the pit-cars hoisted and delivered at the dumping floor of the tipple are various, but as they also have an important bearing on the general design of the tipple structure, some description of the principal styles will be given, premising that all make use of a system of tracks for the pit-cars to run on.



HILTON MINE, IOWA.—TIPPLE OF WHITEBREAST FUEL COMPANY OF ILLINOIS.
Example of tipple with side hoist and flat floor; cars pushed around by hand; stationary bar-screens. Type much used in Iowa and Southwest.

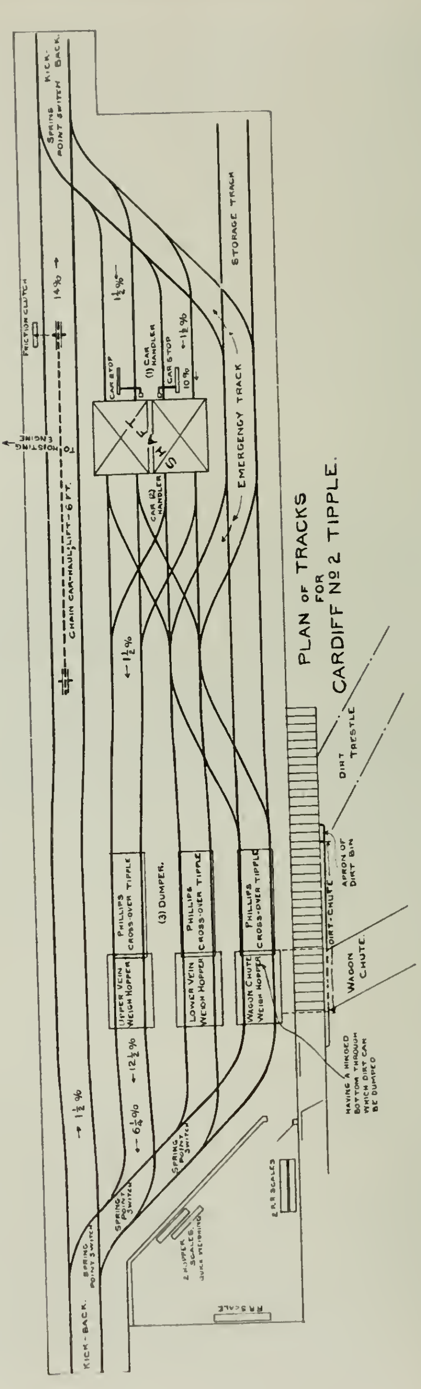
First, that in which the tipple or dump building has a level floor. The loaded pit-cars are run off the cage by hand, and are pushed to the tipping point. After dumping, the car is shoved back onto the cage, or in the better type of tipples of this pattern the empty car is pushed around the shaft, and when the next cage arrives at the top with its load, the empty car is pushed against the loaded car, shoving the latter off the cage and replacing it. In the more improved tipples, through the aid of certain devices, the loaded car is helped off the cage by a slight and momentary tipping of the rails of the cage. This first style of tipple, with and without the modifications mentioned, is the prevailing one in Iowa, Missouri and Kansas; at its best it has a capacity of 1,000 to 1,200 tons of coal per day of eight hours with pit-cars of fair size; that is to say, holding 2,400 and 2,600 pounds, and the shaft not over 300 feet deep. Such a capacity would require five or six men on the dumping floor in addition to the weighman and those employed on the railroad cars. If a considerable quantity of rock had to be handled it might require a couple of more men to obtain the tonnage mentioned. Double-deck cages for this form of dump building would not be of advantage, as the pit-cars could not be handled fast enough to cause a gain; that is, the hoisting capacity would be in excess of the dumping capacity.



CARDIFF No. 2.—TIPPLE OF CARDIFF COAL COMPANY.

Example of tipple and tower with end hoist; with floor arranged with favoring grades; with chain car-haul for raising and bringing empties back to shaft; with three Phillips cross-over car-tips for lower vein, for upper vein and for dirt and wagon chute; two sets shaking screens; double deck cage. Incline trestle at right of picture for refuse rock. See plan on next page.

Second Style, that in which the dump building has a floor arranged to give certain grades to the tracks. By which the pit-car runs by gravity to a cross-over tipple (" Mitchell" or " Phillips"); there, after dumping its load, it is righted, and the next car following automatically opens the locking horns long enough to let the now empty car through. The horns then spring back and catch the incoming loaded car. The empty car runs down a short incline through a spring switch and up a short steep incline, which reverses the direction and turns the car into a track which has a down



PLAN OF TRACKS FOR CARDIFF No 2 TIPPLE.

grade to a point back of the shaft. The car here runs on to a transfer platform by which it is carried sidewise up an incline bringing it in line with one compartment of the shaft. When the next loaded car has been brought up by the cage, a steam ram ("The Ramsey Cager") pushes the empty car against the loaded car, shoving the latter off and leaving the empty car on the cage ready to be lowered into the mine. There is a duplicate arrangement for each of the two compartments of the shaft. The several plants of the Spring Valley Coal Company are arranged in this way.

A variation in this plan is obtained by the use of an automatic chain car-haul to carry the pit-car up to the proper level for running the car on the cage; with this arrangement the grade back of the shaft can be made steep so that the steam ram is not needed. This is the plan worked out by the writer for Cardiff No. 2 tipple where double-deck cages are employed.*

In this second style, with a shaft not over 200 feet deep, pit-cars holding one ton or more, and using single-deck cages with one car, there is no difficulty in obtaining a capacity of 1,400 tons in eight hours; with pit-cars holding 1 ½ to 2 tons, 1,600 tons capacity can be obtained. When shafts are more than 200 feet deep, to obtain a large tonnage it is advisable to hoist two cars at one time. This may be accomplished with double-deck cages, with the use of which the time gained over single decks is the difference between hoisting six or seven feet (the distance between decks) and in hoisting several hundred feet or more, the depth of the shaft. With cars holding 1 ½ tons of coal in shafts not over 200 or 300 feet deep the double deck cage, with either of the arrangements spoken of, should hoist as much as 2,000 tons in eight hours, and with cars holding 2 ½ tons, 2,400 tons per day should be obtained. As already mentioned, there is material advantage in having the two cars on one deck of the cage, as this saves at least three or four seconds needed to change decks in using the double-deck cage. With that arrangement, the writer thinks that from 2,200 to 2,400 tons can be obtained with cars holding 1 ½ tons, and a larger amount with larger cars. It need hardly be stated that two cars on one deck require the shaft to be of nearly double size and owing to the timbering, more than double the cost. It is self-evident that with any arrangement capacities are reduced by the increased depths of shafts. Further, whatever surplus rock has to be hoisted on the day shift reduces the net tonnage of the coal that much. For example, the Spring Valley Coal Company at its several plants hoists all refuse rock on the same shift that the coal is hoisted. Their cars hold about 1 ½ tons of coal, and they get a net output at their No. 1 mine, where they have double-deck cages of 1,300 to 1,400 tons per day, of eight hours, which with the rock is equivalent to 1,600 to 1,700 tons, and this is hoisted from a depth of nearly 500 feet. Spring Valley No. 5,* the plant at which two cars are hoisted on one deck, has not yet reached sufficient capacity below ground to test the hoisting and dumping capacity.

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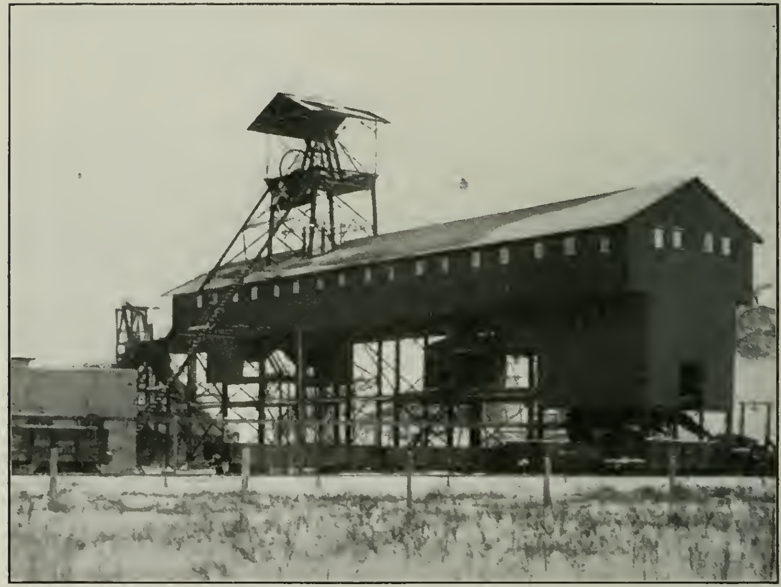
* See illustrations on pages 351 and 352.

The capacities mentioned may not, to some, appear to be large as compared with the tonnage produced in the mines of central and southern Illinois, with the simpler self-dumper equipment. It must be noted, however, that the conditions are more favorable in the latter fields. The pit-cars there used hold from 2½ to 3½ tons, and the depth from which the coal is hoisted is generally less than 300 feet, and in some of the largest mines not over 150 feet, and with no refuse rock to hoist and dump. Regular daily outputs of 1,600 to 1,800 tons per day of eight hours are obtained by a number of mines, which on spurts are run up to considerably over 2,000 tons.



SPRING VALLEY No. 5 OF SPRING VALLEY COAL COMPANY.

Example of tipple and tower with end hoist; floor arranged with favoring grades; Ramsey transfer tables with steam ram; stationary bar-screens; two cars hoisted on same deck of cage, end-and-end.

This picture exhibited through courtesy Mr. of S. M. Dalzell.

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*This was the plant visited by the Western Society of Engineers, October 5th, 1901, on the excursion to Deer Park.

It has been the common practice to design wood tipples without going very fully into details of its later use. It was much the same way with the first steel tipples, and insufficient strength was allowed in the early structures for adequate stiffness, and this caused something of a prejudice in the minds of some coal operators against the use of steel. Now, the necessity of more weight in the individual pieces than is strictly called for by the strain sheet, is apparent to most builders. As shaking screens are bound to cause some vibration in their supporting frame unless the latter has excessive weight, it is now the usual practice to not connect this frame to the main building. The railroad track scale beams, also the weigh-hopper scale beams, are customarily placed up in a weigh-room on the tipple floor of the main building; and any considerable vibration interferes with accurate weighing. This is the main reason why it is inadvisable to connect the frame with the tipple building. While the dumping of the cars is also apt to make some shake, it is not continuous as with shaking screens.

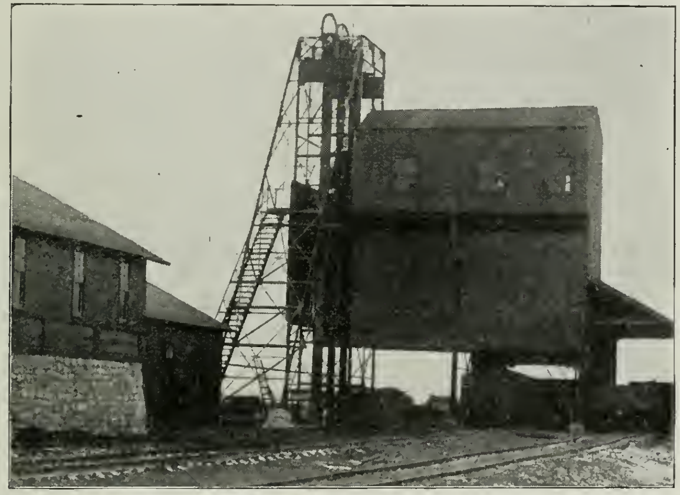
The greatest working strain thrown on the structure is in hoisting cages. The latter with their load and the hoisting rope, weigh from two to four tons for the simpler kinds, and from six to eight tons for cages holding two cars. The hoisting engines are usually made with a considerable surplus of power, so that in starting to hoist, they are apt to pick up the cage with a jerk. In this way the strain may be increased from two to three times the dead load. Another great strain that may be thrown on the tower structure in using rigid cages, comes from the pound of the cages as they land on the "rests" at the floor level. This may be very heavy with double-deck cages, if the engineer is not very careful, and this contingency must be allowed for. In the case of self-dumping cages the pound is avoided. On the other hand, with the latter there is considerable horizontal strain due to the reaction in quick tipping and dumping which must be taken care of. The most difficult problem in each case is to take care of the horizontal strain produced by hoisting. The hoisting engine is usually placed somewhat away from the shaft so that the rope makes an inclination from the horizontal of from 25 to 75 degrees, depending on the idea of the party laying out the plan. The writer's view of this is that the hoisting engine should be placed a considerable distance away from the shaft, not only with a view to safety from any fire originating in the mine and coming up the shaft, and also to be away from any settlement of the surface about the shaft (unless the foundations can go to rock), but chiefly because it is less trying on the hoisting rope. The latter is on two accounts: when the rope is inclined so that it sags slightly, there is a certain amount of elasticity due to this. The limiting inclination is that at which the rope does not require rollers for its support. The writer has found that an inclination of about 40 degrees from the horizontal is usually about right. The other reason for a considerable distance of engine from the shaft is to lessen the angularity of "wind" on the drum; with a deep shaft there is necessarily a wide drum. In such a case it becomes a matter of necessity to have ample distance.

With wooden tipples it is customary to run the "engine brace" from the engine foundation to the frame carrying the sheaves. In hoisting, the resultant of the strain bisects the angle which the vertical part of the rope makes with that part running to the engine. In an extreme case, produced by an over-wind where the detaching hook is not used, or by any other kind of accident where the cage is lodged in the upper part of the tower, the line of the resultant would be almost directly along the hoisting rope from the sheave to the engine drum. The engine brace then takes practically the whole strain and, if strong enough, prevents the over-turning of the tower. Some of the present steel tipples have the engine brace from the sheaves to the engine foundation; in others it follows the line of the resultant. In many the engine brace is not designed strong enough to break the hoisting rope before yielding. Although the writer always advises the use of detaching hooks, to allow for any possible chance of their not working, he assumes double the breaking strength of the rope in figuring the ultimate strength of the structure.

With wood structures that are not tied down to heavy foundations, it is necessary that the resultant should fall between the engine brace and the tower; in other words, within the base, but this is not the case with steel structures. The writer, accustomed to design wood structures, did not at first come to the full realization of the difference in material, but tended, in his first steel structures, to follow the lines of wood designing. This has evidently been the case with other engineers from inspection of the structures that have been built. Latterly, the writer has so far got away from this feeling as to have accepted in the Cardiff No. 2 tipple, a very novel design of our fellow member, Mr. Andrews Allen, who submitted this design as a substitute for the one proposed by the writer, which followed more conventional lines. This Cardiff No. 2 tipple is shown by the accompanying photographs. The tower proper it will be observed has an "A" shaped frame, symmetrical with reference to the center line of the shaft (see frontispiece.) When the full strength of the tower is developed it is necessary to depend on the weight of the foundation under the back legs; that is to say, those further away from the engine, to prevent over-turning. This is properly allowed for in the design of the foundation. The tower proves very stiff in operation and there is no vibation in hoisting and lowering the cages.

A considerable variation in tipple structures is produced, according to whether the engine is placed directly behind the shaft, in which case the sheave wheels are side by side, or whether the engine is placed at the end of the shaft, in which case the sheaves are either one above the other, as in the Cardiff No. 2 mine, or are placed lapping and making a slight angle with the vertical plane through the middle of the shaft, as in the Dunfermline tipple, also shown in an accompanying photograph.

The relative merits of the several possible locations of sheaves and engine is a matter of controversy, though all agree that it is advisable to place the engine house near or adjoining the boiler house. The majority of builders place the engine back of the shaft, i. e., at the side, because it is simpler to construct the head frame in that way. The writer prefers to place the boiler house along side of the railroad track, (so that coal for the boilers can be unloaded from the cars direct into the boiler house, when desired,) and to place the engine house close by, thus requiring "end hoisting."



DUNFERMLINE "C" TIPPLE OF WHITEBREAST FUEL COMPANY OF ILLINOIS

Example of tipple with end hoist for self-dumping cage; with weigh-hopper; stationary lump-bar-screens; screenings hoisted by elevator for rescreening over shaking screens.

In the matter of details for the steel structure, the writer has these suggestions to offer:

First, built up pieces should be as simple and compact as possible. All lattice work to be avoided. The cross section of the members should be such that they can readily be painted on al surfaces. Angles or other pieces constituting a member should b offset, where necessary, to avoid small spaces, or else fillers used

Second, rod braces should not be used. All light braces should be angle bars.

Third, angles, plates and webs of any shapes should not be less than 5-16 of an inch thick, regardless of how light the strain may be.

Fourth, all main parts of the tower should be kept as far back from the shaft as possible, in view of a possible fire originating in the mine, also to keep the foundations away from the shaft.

Fifth, the structure should be shipped in as large riveted sections as possible, and field bolts should be used in erection on the ground. This saves expense in comparison with field riveting, and if the structure is to be taken down in the future for moving elsewhere, it is of advantage. The writer has found no difficulty from the field bolts getting loose.

Sixth, as responsible structural building concerns are in position to give the best design suited to their shop, for the least money, provided they have full knowledge of the requirements; it is advisable for the coal operator who may submit his own plans for bids, to invite suggestions for improvement.

Now as to the relative merit of steel as compared with wood construction. There are two questions usually asked by prospective builders about the use of steel. Is steel durable under the conditions it is subject to at the mine? And is the greater cost of the steel structure justified? The writer thinks that there is no question but that steel is more durable than wood. In this part of the country it has been put to a test of nearly ten years without appreciable weakening. In the matter of first cost, whether or not the operator is justified in employing steel is more open to argument in small plants. It may here be stated that a steel tower and tipple complete will cost, approximately, double the cost of a wood structure. In some places in Iowa, for instance, a shaft rarely has sufficient field to last over ten or twelve years; the average life time of a wooden tower is sufficient for this. On the other hand, if a steel structure be used and put together with bolts there is a salvage value which the wooden tower will not have; furthermore, a fire which might originate in the wood tower is liable to set fire to and destroy the mine. In the latter event, under the best of circumstances, the mine would be out of business for a couple of months, and thus cause a loss that would probably be far greater than the cost of a steel tower. That such fires are not infrequent can be seen by looking over the State Mine reports. During the past year, several wood tipples have burnt in Illinois.

As to the mines of large capacity, it will hardly admit of argument that steel should be employed, and as seen by the writer, the feature of fire protection is sufficient to justify the employment of steel in all shaft tipples, small or large.

DISCUSSION.

Mr. Warder—What is the length of the pit-car tracks as shown in plan view of the tipple floor?

Mr. Rice—The extreme length is about 140 feet.

Mr. Liljencrantz—How many tons a day do they handle at this mine?

Mr. Rice—Only about 400 to 500 tons a day at present, as the mine is new, but the expectation is that 1,800 to 2,000 tons can be handled in eight hours.

Mr. J. F. Jackson—There was one point that came to me during the reading of the paper, and that was that the hoisting done in the iron or copper country, being very much more severe, requires larger structures than those in the coal countries. In the iron and copper country the hoisting engines are put back about 400 feet or more from the shaft, for the reason that very large drums are required; the drums are frequently 20 feet in width and 25 feet in diameter. The angle of the rope therefore changes considerably, and it is necessary to go back far enough to allow for that change.

In the iron country about ten years ago the times were very hard, and they tried to get along with the fewest possible number of men. In some cases there were only one or two on the head frame, but the conditions were quite dissimilar, and I did not intend to make a comparison between the iron and copper and the coal countries. However, I think possibly a greater saving could be made in the number of men used on those coal tipples. I know of one iron mine where a large tonnage is handled, and one man attends to the whole thing.

Mr. Rice—One essential thing in soft coal mining is to prevent the breaking of the coal. The lump coal is so much more valuable than screenings that we make every effort to prevent breakage, and that is the reason pit-cars are hoisted and dumped on top rather than dumped below into "skips." Although the use of the latter effects a slight saving in the hoisting and dumping expense, another objection to "skips" is that they are not available for raising and lowering the miners. In large mines employing 500 to 800 men underground, this is a matter of importance.

Mr. Finley—Railroads for their locomotive use now require that the coal be broken into egg size, and this is done at considerable cost to them at their coaling stations. Suppose a railroad company takes the entire output of a mine, the breakage mentioned by the use of skips would not be of importance, since the railroad wishes the coal in smaller size than lump.

Mr. Rice—This might be true if the railroad would take all the product, but this they will not do, and they do not want the screenings. We have had it proposed to our people that we crush the coal at the mine before shipping, but we, as a commercial company, could never see the point from our side, since when you come to break up the coal you produce, through the process of crushing, such a large amount of fine screenings which has to be sold at the mine at one-quarter to one-half the price of the lump from which it has been produced.

Mr. Finley—Some of the railroad companies have rules requiring that the coal be broken up before loading on the locomotive tenders. It seems to me it would be an advantage to have it broken at the mine rather than at the coaling station, in the case where the railroad company owns the coal mine.

Mr. Rice—I would not advocate it myself. The coal in this part of the country after mining rapidly loses its strength, and by exposure to the weather; every fresh surface, produced by crushing, gives a chance for further weathering. Even under the circumstances you mention it seems to me it pays better for the railroad company to break its own coal right at the bins. The C., B. & Q. R. R. Co., has quite a good system for doing this at their Galesburg coaling bins. They have a grate or screen of heavy flat bars set on edge reaching across the double bins at intervals of 6 inches apart. They back a train of coal cars up an incline trestle over these bins, usually using bottom dump cars; the screenings fall through, and attendants provided with picks and sledges, hit the lumps as they rest on the bars, breaking them up with a minimum of breakage, the pieces dropping through into the pockets.

Mr. Finley—But that adds to the cost of handling.

Mr. Rice—Yes, but that additional cost is very insignificant; I am told the extra cost is only about 2 cents for handling the coal in that way up on top of the bins. I think this covered the cost of dumping the cars, shoveling and breaking it, to allow passing through these bars. It cannot be done as cheaply as that at the mines considering the crushing and rehandling, without taking into account the wastage before mentioned.

Mr. Finley—In the coal mines do they use the diamond bar screen?

Mr. Rice—Yes, it is more or less used by the railroad companies but not by the companies selling commercial coal.

Mr. Finley—Are railroad mines using it for the reason that it does break up the coal more?

Mr. Rice—No, it is because of its simplicity and less expense both of first cost and that of operation. Further, it gives a sufficently good screening for the purpose.

Mr. Jackson—Have any experiments been made to determine the extra breakage of the coal that might be caused by using skips over that by hoisting the cars?

Mr. Rice—No, I cannot say that there have been. I may add there are objections to dumping coal down in the mine. It has to be weighed before dumping, and this has to be done more or less in the dark, and a good many of the miners are apt to take advantage of that condition and load more rock with their coal than if their cars were hoisted to daylight where the coal can be better inspected. Very frequently they have to stop a pit-car to pick out rock or bad coal, which would be difficult below ground. This condition does not exist in the copper and iron mines.

Mr. Schaefer—I would like to ask Mr. Rice if he can tell me about what the per cent of increase is, at Spring Valley mine, by using double deck cages over single deck cages, in the case of the 500-foot hoist.

Mr. Rice—No, I cannot say, in that case, because it is complicated by other conditions. That particular company hoists rock on the day shift; by so doing they evidently lose something in coal output. It is a labor condition that confronts them in that, and they think they gain by it, whereas the majority of operators believe it is best to hoist the rock on the night shift. This prevents making direct comparisons.

Mr. Schaefer—Have you any idea of the per cent of this increase?

Mr. Rice—Theoretically it is a matter you can figure out pretty closely; you know the speed of hoisting; you know the length of time it takes to hoist—say 500 feet—and you know the length of time it takes you to stop and take off and on the cars in a given case; therefore what you save in that case is the difference in time in every second hoist between a hoist of 500 feet and that of 6 feet. It would figure out something like this. Hoisting 500 feet and landing cage 10 seconds; hoisting 6 feet and landing cage 4 seconds; changing pit-cars 5 seconds; total for one deck 500 feet, 15 seconds; total for second deck, 6 feet, 9 seconds; average for double-deck cage, 12 seconds. This would give for single-deck cages an output of 4 cars per minute; for double-deck cages, of 5 cars per minute or 20 per cent more; this is only for the depth specified. It is evident that for shallower shafts the gain will be less until it becomes practically nil; on the other hand in deeper shafts the gain is proportionately greater.

Mr. Schaefer—How often is it necessary to paint these tipples?

Mr. Rice—If they are quite closely in contact with the shaft, they ought to be painted every year.

Mr. Schaefer—Have you had any experience with galvanized iron as against black iron?

Mr. Rice—Only in the nature of roofing. In that way the galvanizing is very successful. I never use now the plain black roofing around the mine, on account of corrosion. To show how rapidly corrosion takes place when unprotected—there happened to be a cross-brace immediately at the top of the old Cardiff No. 1 mine; it was rather unimportant and was located in such a place that it was not convenient to paint it, but when we uncovered it we found the scale that had collected on it was about 3-16 of an inch thick, a result of three years' exposure.

Mr. Spielman—I believe that the wooden tipple you speak of at Spring Valley was burned during a strike, (I think the steel tipple was manufactured by a Pittsburg company—the Pittsburg Bridge Company), and I also believe that the acute stage of the trouble did not develop until the tipple was partly manufactured, when the sides of the shaft caved in, necessitating a new location and design for tipple.

Referring to the shaker screens and the enormous vibrations that are experienced, I was wondering how you got at the units you used there. As I understand it, there is shafting of perhaps 4 or 5 inches diameter revolving very rapidly, with a load of several tons. I was wondering whether you treated that as an impact or whether you assume very low unit values for the members affected.

Mr. Rice—I think no one attempts to figure the stresses, as they are very complex; the present designing is rather a matter of experience. We all started to use rather light structures, but kept on making them heavier, as the result of experience. The strength needed is surprising, considering that the power required to run these shaking screens is insignificant—a matter of several horse power only.

Mr. Schaefer—My rule has been to make it one day as heavy as I dared, then sleep over night, and come down the next day and make it twice as heavy.

Mr. Finley—Tipples vary so much in design and proportioning that I am inclined to think there is considerable room for striking a happy medium.

Mr. Spielman—About what class of hoisting cables are used in the Spring Valley mines?

Mr. Rice—I believe they use from 1 ¼ to 1 ½ inch diameter rope according to the different loads at the several mines. At Cardiff mine, we use a 1⅜ inch diameter rope of "extra crucible steel" and which has a breaking strain of 78 tons.

Mr. Jackson—I haven't much faith in the ability of shaking screens to shake a sufficiently heavy structure. I have never found any great difficulty in providing for heavy crushers operating 20 feet above ground, or providing for engines of 50 or 60 horse-power at a considerable height above ground. Particular attention should be paid, as Mr. Rice has said, to bracing to the ground as well as possible.

Mr. Rice—I do not think the comparison is quite fair. The class of structures to which Mr. Jackson alludes, employ large heavy bins, which in themselves have considerable inertia. Then the type of machine mentioned is entirely different; the rock crushers' stresses are internal, and such engines as mentioned are largely self-contained. I am somewhat familiar with what is required for the support of these, and I do not think they will compare with a large shaking screen in producing external stresses. However, in the case of the head frames for iron mines to which Mr. Jackson alludes, in which there are these large bins to support, the columns required therefor and their foundations have to be so heavy that shaking screens themselves would have no effect on such a structure.

I had not meant to give the impression that there were enormous forces to meet in the use of shaking screens, but rather that the weights were relatively so light for structural steel buildings, that they were apt to be ignored with bad results.

I think that all will agree that the best engineering is that which accomplishes proper results with the smallest expenditure; so perhaps it was better that, in starting, such structures were built too light rather than too heavy, for experience with the former has taught us the intelligent strengthening of the weak points.

Mr. Andrews Allen (by letter)—The writer is very glad that the problem of steel tipple designing has at last reached the field of academic discussion. Much may be gained by comparing results obtained by different designers and by noting and correcting progressively the mistakes made in previous designs.

As Mr. Rice has said, the stresses and strains existing in a tipple were not sufficiently understood and appreciated by the early designers, and more than this, the working conditions and the conditions affecting the permanence and durability of the structure do not seem to have been understood and appreciated any better.

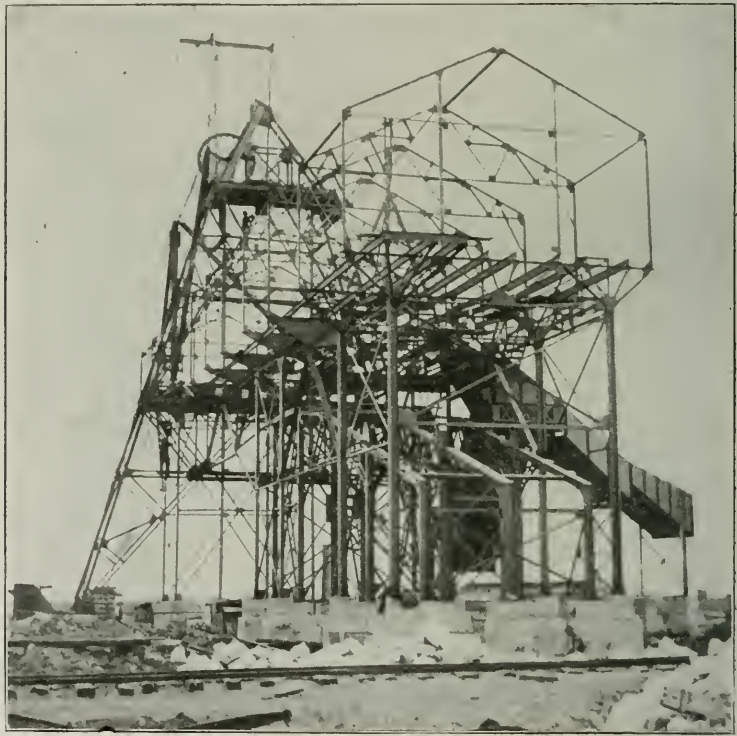
The writer has made somewhat of a study of tipple construction for a number of years. Like all the rest, he followed at first the lines of the wooden tipple, for want of a better example, but the defects became apparent after practical test and were of such a serious character that in his more recent designs he has broken entirely away from the old forms and attempted, with more or less success, to treat the problem from an engineering point of view—that is, given certain duties to perform, and steel as the material to be used, to determine the best and most economical design and proportion.

The duties to perform and the working conditions as conceived by the writer are as follows:

1st. The head frame must be of such a design as to resist the strains of hoisting and dumping; to withstand without injury the crucial stresses caused by any possible breakage or disarrangement of the machinery, such as an overwind, lodgment of the cage or throwing off of the car when dumping.

2d. The shaker structure should be designed so as to allow the greatest freedom in future arrangement of screens and must be proportioned for the constant and rhythmic vibration of the screen.

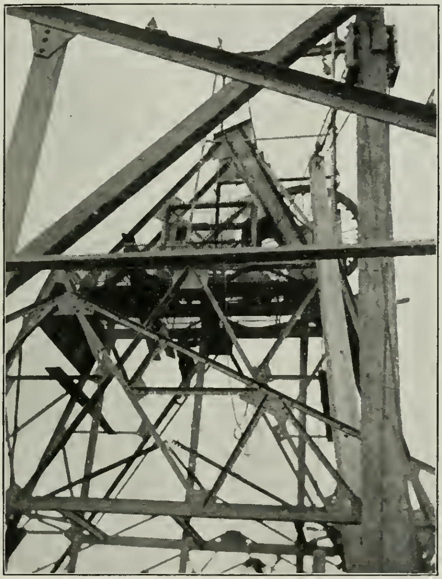
3d. As good foundations are essential to the above, and as, except in solid rock, the curbing of the shaft or the ground immediately around it does not afford a solid foundation, on account of possible settlement and lack of solidity; all foundations should be carried as far as possible away from the shaft.


STEEL FRAMEWORK FOR CARDIFF No. 2.

4th. As the gases and fumes coming up the shaft or blowing from the waste dump are very destructive to steel, the members entering into the construction of a tipple should be few, heavy, compact, easily painted and with no recesses. They should also be carried as far away from the shaft as possible, and for the same reason, there should be no housing over and around the shaft above ground.

An operator is foolish to spend the money for a steel tipple unless he obtains a structure that is permanent and that cannot be injured or crippled by any accident to his machinery. The tipple should therefore be designed of sufficient strength to break the hoisting cable, and no essential parts of the tower should be arranged so that they can be injured by an overwind.

Working out a design on the above lines led to the plan of Cardiff No. 2 as described by Mr. Rice. Here the writer used what may be called an "A" frame tower. The legs battered equally and were about 50 feet apart at the bottom. The bracing consisted of struts inclined from the base to an apex at the center of the platform and again from the edges of the platform to the center of the sheave deck. A second "A" frame holds the sheaves. The feet of the tower are securely anchored to concrete piers of sufficient weight to take care of any possible uplift and they are connected across by heavy rods imbedded throughout their length in concrete, thus forming a strut and tie practically below the ground and of a form that ought to be absolutely permanent. This tower proved remarkably stiff and with modifications, has been the model of several subsequent designs by the writer.


HEAD FRAME OF CARDIFF No. 2 DURING CONSTRUCTION.
Showing Upper "A" Frame Carrying Sheaves.

In regard to the shaking screen structure, the writer is not at all hopeful of finding a correct analysis of the stresses. The effect of rhythmical vibration is hard to measure—as witness a horse trotting over a bridge or a company of soldiers marching in step. The writer has known the heaviest of paved highway bridges to vibrate perceptibly when a dog trotted over it, and at the same time to be absolutely stiff under the heaviest teaming. Where the shaking screens are attached to the main tower there is a tendency for the vibration to be multiplied and intensified towards the top, and when the screens are put into motion every piece of the structure will vibrate more or less in unison. Now while the writer believes that it is quite possible to design and build a structure so stiff and strong that the screens can be attached to it without serious vibration, he does not believe that it is economical to do so. The writer would prefer to separate the structures, let the screen structure vibrate a little if it will, but keep that vibration away from the scales and weigh room above.

Next in importance to the above, is the making of all individual pieces stiff enough not to vibrate of themselves. The braces are mostly figured as ties but they should all have sufficient radius of gyration in proportion to their length to enable them to act as struts. Whenever a piece vibrates it shortens and lengthens a trifle, which sets up vibrations in the entire structure, and these vibrations are often cumulative until a tower may be (as they say of one down in Indiana) "Like a tuning fork." When each member is stiff in itself such vibrations do not spread and are therefore harmless.

The end hoist and the side hoist tipples require radically different treatment. In the side hoist, the shock of dumping is in the same plane as the pull of the rope and can be provided for readily by connecting the dumping floor to the engine brace (the writer generally uses an engine brace in side hoist tipples.) With the end hoist tipple, the shock of dumping acts at right angles to the cable pull and shocks and stresses in both directions must therefore be provided for. It is usually necessary to build an end hoist head frame wider than a side hoist head frame for this reason. In such a tower however, as at Cardiff, where self-dumping cages are not used, there is no such shock to be provided for and the tower can therefore be made narrow, but the shock of dumping must nevertheless be provided for in the platform by longitudinal and horizontal bracing.

The writer has made it a practice to examine and note the defects in design and construction of each tipple he has built. These defects he always attempts to correct in the next design and the process of evolution has been going on a good many years. It is easy for one with unlimited money, or rather with a customer willing to pay without limit, to design a strong and stiff tipple and that with a very elementary knowledge of the problems involved. But it is not so easy to meet the conditions and at the same time suit the pocket book of the operator. The writer believes, if he lives long enough, that he will some day build a tipple that will satisfy him, but although a great deal of progress has been made, he is very unwilling to consider the present state of the art as a finality or to say that in the future even more progress will not be made than has been made in the past.

The steel tipple in the West has been injured by its friends. Many will say that it is a failure, but they judge from the examples they have seen, and the writer regrets to say that there are very few good steel tipples in the West, (the writer confesses to several that will not pass muster.) But the few that are satisfactory point the way to still better things. A good wooden tipple is far better than a poor steel one, but a really good steel tipple is immeasurably better than either and is the ideal construction. The day ought to come when the operator of a large mine will no more think of installing a wooden tipple than he would a wooden hoisting winch operated by "the American Hay Burning Engine."

RAILROAD SIGNALING.

G. E. Ellis, M. W. S. E.

Presented April 20, 1904.

The title chosen for this paper covers a broad subject, but it was considered more desirable to present to the Society a few of the general principles of Railroad Signaling rather than to enter into a discussion of the details, many of which are not even yet agreed upon by experts in the art. Probably much will be said that is not new to many of the readers of this article, but we trust that something of interest may be discovered by all. There are many topics which come to the mind of those connected with Signal work, the complete discussion of any one of which would make a paper of prohibitive length, but these discussions are generally of interest to Signal Engineers only and would be entirely out of place before this Society.

A brief definition of "Signal Engineering" may he given as that branch of railroading which tends to make the operation of railroads more safe by giving a positive indication to the trainmen of the condition of the track in respect to other traffic. This is a very general definition, but it covers all the branches of the art. While signals often serve other purposes, yet they are primarily installed for this end. Thus in automatic signaling a broken rail will be indicated by the signal, and while that is an important safeguard, the installation is not made for that purpose alone.

We may possibly make two arbitrary divisions of the subject: that which has to do with isolated cases, giving protection to places that are in themselves considered especially dangerous, such as grade crossings, junctions, and drawbridges, and second, in the protection of long stretches of track not in itself dangerous, but where it is desired to facilitate traffic. Our definition however, holds in either case, although with drawbridges it is water traffic that may be considered, as that to be guarded against. With junctions and grade crossings, the whole installation is designed to give protection against the trains on the other tracks concerned by warning the engineer of an approaching train whether or not any other trains are in his way. For the second division of the art we try to render the operation more safe while at the same time permitting higher speeds. These two branches merge into each other so that in the most complete installations, and for the end towards which all roads are striving, all crossings, junctions and main track switches would be protected by interlockings and the track would be controlled by a complete block system, all working in harmony.

We will consider first the former class, both because it is more generally distributed and because its principles are used in the second class. Apparently, interlocking originated in England, in the early days of railroading. The practice of grouping the levers for a series of switches, and also the use of signals to control the movements of trains seems to have developed along independent lines at first. It was found that as the groups of switches increased in size there must be some connection between them and the signals; otherwise it was possible to give a false indication by the attendant through carelessness or some other cause. The interlocking between the levers was introduced about 1856 by Saxby in England.

In this country the first interlocking machine was erected near Newark, N. J., about 1870, and that machine of 20 levers imported from England is now preserved in the Field Columbian Museum. It has a very close resemblance to many machines of our latest make. About the same time Messrs. Toucey & Buchanan of the N. Y. C. & H. R. R. R., developed an interlocking machine of their own. This had its locking in a vertical plane below the operator's floor, while the "Saxby & Farmer" machine above mentioned had its horizontal locking above the floor. Several of these Toucey & Buchanan machines were erected between New York and Buffalo, the first being at Spuyten Duyvil, 10 miles from the Grand Central Station, New York City. One was erected at Batavia, N. Y., at the crossing of the Erie R. R., and is still in service. From the time of its first introduction, the use of interlocking rapidly increased until it is found in nearly, if not quite every state and territory of the Union, but it is impossible to give the number of the levers in service. Several of the states have taken official recognition of the safety afforded by interlocking devices by giving the Railroad Commissioners more or less authority over such matters. This varies from a simple inspection in some states to an actual ordering by the state that a certain number of points are to be protected each year.

An interlocking plant may be considered to consist of two parts, the signals and the switch controlling devices. By the former, the desired indications are given to the enginemen, and by the latter, the safety of any desired route is assured. The signals being the part most apparent will be first considered.

The semaphore type is now universally used. This originated in England after exhaustive tests as to the most visible form of a signal, although it had been previously used in transmitting messages from point to point forming a sort of visual telegraph. Depending on its use, the semaphore has been given various names. In interlocking, now under consideration, generally only two forms are used, the "home" and the "distant" signals. A home signal is illustrated by Fig. 1. In construction it consists of a post extending about 25 feet above the rail, and either of wood or of some form of iron construction according to the most approved present practice. The indication is given by the blade, extending from near the top of the pole to the right as seen by an approaching train. When the blade is in a horizontal position it means stop or caution, but when inclined or vertical the signal is for clear track or proceed. The blade is fixed to a proper casting which supports a light on the other side of the pole, giving the night signals by means of colored glasses. The night indication is by color—but the day indication is by the position of the arm or blade. The face of this blade is generally painted red, but some roads recognizing the inconsistency of allowing trains to run

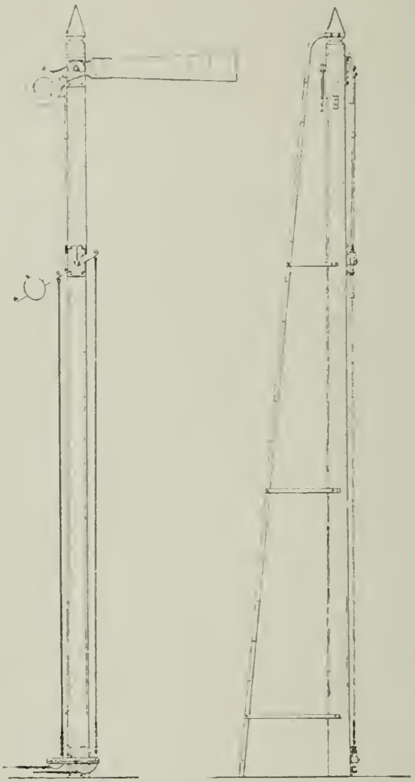


Fig. 1. Semaphore Signal.

past a *red* signal, have adopted a neutral color, as yellow. The proper location of the home signal is at the point at which a stop is desired. It does not necessarily mean danger, although the stop position is usually spoken of as the "danger" position. There may be more than one home signal in an interlocking system for each direction if the distance between the operated switches is great. Good practice should not permit a signal to be too far from the switch it controls, and 200 feet is often considered a maximum, although local conditions may alter this.

The home signal may have more than one arm, as two arms are used where there are diverging routes, the upper arm indicating the more important route and the lower arm the less important one. Sometimes three arms are seen, where there are several routes, two or more of which are of importance. Where the signal cannot be placed adjacent to the track it governs, a bracket pole is used, with stubs indicating the number of tracks between the track signaled and the signal. It is becoming the practice to simplify the form of bracket signal, often using but one dummy even should there be more than one track intervening, especially since the engineman at high speeds has no time to count the dummy posts, and it is usually evident to which track the signals refer without the use of any device to make it plainer.

The distant signal differs from the home signal chiefly in the color of the blade, which is usually green or yellow, and also in having the end of it notched or fish tailed. The night indication also differs in color, although the English practice is to make no distinction. The distant signal commonly has but one arm, referring to the upper arm of the home signal, if that signal has more than one arm. The location of the distant signal should be at such a distance from the home signal that the fastest trains may stop at the latter provided the train is put under control the instant it passes the distant signal. This distance varies from 1,200 feet to 3,000 feet depending on the average speed, grades, etc. The lesser distance is an arbitrary one and was a few years ago universally used. While a train can often see a distant signal before it reaches it, yet consideration must be given to the fact that in fogs, when signals are the most useful, no signal can be seen until it is reached. The indication of the distant signal when in the horizontal position means to proceed with caution, and be ready to stop at the home signal. When the arm is inclined it means that all signals for that route are clear and that the train may proceed at speed. The distant signal may be placed on bracket posts or on a light bridge over the tracks, just as with the home signal.

A miniature home signal called the dwarf is used to signal movements from the sidings to the main track, or a reverse movement onthe main track. Its colors and indications are the same as for the home signal and its location the same in reference to the switches. It is so small that it can be placed between the tracks without interference from passing trains.

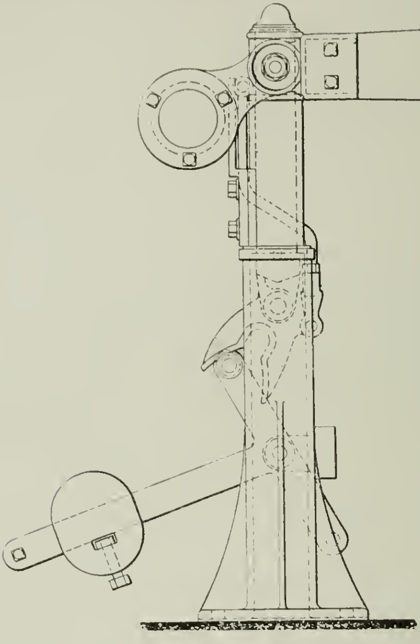


Fig. 2. Dwarf Signal.

We have said that, the "clear" position of all signals is inclined or vertical. Most roads use an inclination from the horizontal of about 60 deg., but many engineers favor an angle of 90 deg. This gives a fine appearance to the signal when in the clear position, but it is objected to on the score that from certain points of view, it may appear merely as an enlargement of the pole and is therefore not sufficiently distinctive. With the throw of 60 deg. there is no doubt as to the signal, for the blade cannot be hidden by the pole.

The American Railway Engineering and Maintenance-of-Way Association has adopted a 90 deg. throw as standard for "train order" signal, and many roads are now using it for all semaphores.

As above stated, the night indication is by color only. The most common practice until very recently, and still largely used, was white for safety and red for danger with home signal and green for caution in the distant signal. The use of a white light is generally recognized as liable to confusion with other lights, especially should the signal light become extinguished. Since the light itself is white, and the distinguishing color is had by the glass in the blade grip, should this colored glass become broken a "clear" signal would be shown when a stop might be intended. This however, has not been found to be as serious as mistaking some other light for that of the signal. Undoubtedly most roads would adopt green for clear track were it possible to secure a good distinctive light for the distant signal. Yellow has been tried and is largely used for the caution position of the distant signal, but is not entirely satisfactory. A combination of colors is also used, but that either requires two lamps or one of special design, either of which methods is expensive. For lack of a better solution yellow is gradually gaining ground. Many roads on new work now arrange for two color indications even should they not immediately adopt some other color than white for a clear track, but they recognize the fact that the change must be made eventually. For dwarf signals the same colors are commonly used as for the semaphores, but some signal engineers have adopted purple for stop indications at night as the red is sometimes in danger of confusion, since the location of the dwarf often brings it directly in range of the engineman's vision, although it may be intended to govern another track.

A few years ago it was considered desirable to give a separate signal for each route. Since in a switch-yard this would require an impossible number of blades on each post, a device known as an indicator was invented. This consisted of a large figure or symbol so arranged that it would be thrown into view, to indicate the route that was to be taken. Indicators have been abandoned in this country and it is doubtful if one could now be found in operation. In view of this, it is interesting to note that an English engineer has just invented and put into use on his line what is practically an indicated signal.

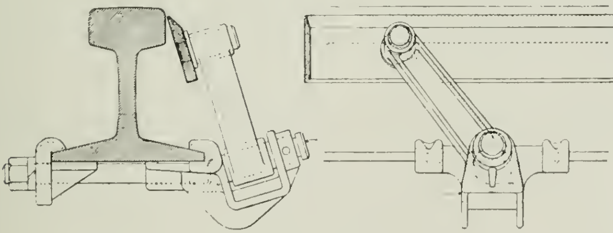


Fig. 3. Detector Bar.

Of the switch controlling devices perhaps the most important is the "detector bar," which consists of a flat bar of iron supported by clips close beside the rail. These clips are either secured to the tie or directly to the rail and are so designed as to permit the bar to be raised up above, but inclined a little from the vertical towards the center of the rail. This is accomplished either by links pivoted both on the clip and the bar, or else by an inclined slot so designed that when the bar is moved lengthwise it will be raised the proper distance of about one inch. As this bar is now used 50 feet in length it will cover the space between the wheels of any car, so that if a car is over the bar it cannot be raised, thus holding the switch locked and preventing the operator from throwing it under a train. In this country detector bars are always placed on the outside of the rail. Where switches are close, or there is not 50 feet of clear track in advance of them, two or even three bars may be needed, so that every possible route may be protected by 50 feet of bar. The bar is worked usually by the lock lever, in connection with the facing point lock. This name is usually applied to the whole apparatus. The lock itself consists of a plunger passing through a hole in a bar attached to the switch and so closely adjusted that the plunger cannot enter the hole unless the switch point faces up close against the stock rail. Should anything drop between the rails to keep them separated, the plunger could not enter its hole, thus preventing the lock lever from being thrown, and hence the signals could not be "cleared" until the trouble had been located and remedied. Two or even more locks may be attached to one lever, but good practice considers two full bars or 100 feet in length, a fair load for the operator, although if distances are

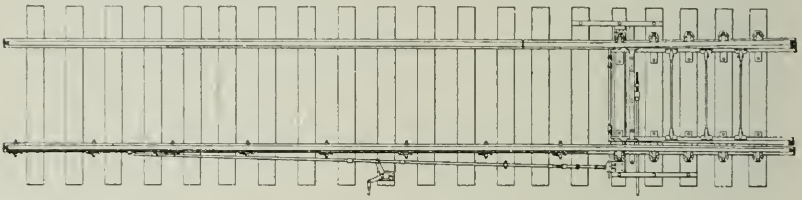


Fig. 4. Facing Point Switch.

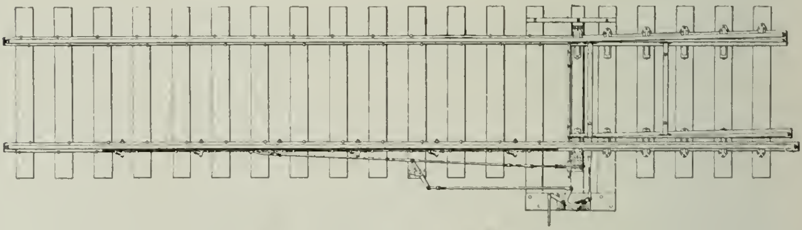


Fig. 5. Switch and Lock Movement.

short this load can be a little exceeded. It is sometimes difficult to get the proper bars on a double slip switch without overloading, but by allowing two lock levers to each such slip, the loads can usually be brought down to within proper limits. Formerly only one lever was used for a slip with a load so heavy that it was difficult for one man to handle it.

The switch and lock movement is an ingenious device whereby one lever is made to do the work of two. When it first came into use, it was not properly used, as two were sometimes placed on one lever, making an excessive load for the operator. Apparently on this account it fell into disfavor and was almost entirely discarded for a while. It has now come into use again, even on main track derails, at crossings, although only one is now placed on a lever and its movement is checked by bolt locking the signal. The movement consists of some kind of an escapement so arranged that the first part of the lever stroke unlocks the switch and raises the detector bar; the second part of the motion throws the switch and finally the bar is dropped and the switch locked in its new position. There are several different forms but they all work on this principle.

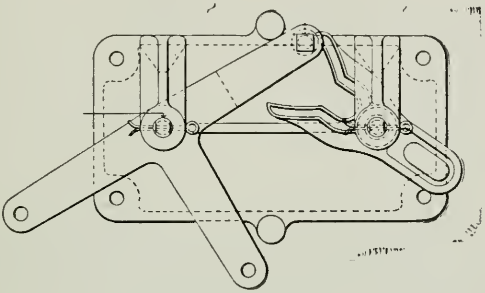


Fig. 5a. Detail.

The bolt-lock is a simple device introduced into the line of pipe, or wire operating any signal, and consists of a flat bar of iron cut into the line and therefore moving with it. This is placed right opposite the switch it is desired to protect and a bar directly connected to the switch moves in the bolt-lock frame at right angles to the first bar. There is a notch in each bar, so that when the switch is in proper position, the notch in the switch bar will permit the signal bar to move and the signal to be "cleared." Then the switch is locked and cannot be moved. Should the switch be moved first, the signal is locked at "stop." It is customary to place bolt-locks on the derails for the home signals, and sometimes for distant signals. Occasionally a facing point switch is bolt-locked with each arm of a two-armed home signal, so that the wrong signal cannot be given should any connections be broken.

The connections by which the various functions are operated may be either pipe or wire, in mechanical plants. The latter is used exclusively for switches, locks and all track connections. In the best modern practice, pipe is used for home signals and occasionally for dwarf signals. Wire is used for the distant signals, usually for dwarfs, and still quite frequently for all signals. A few years ago, wire or cable was used to operate switches or derails and possibly a few such plants can still be found. When distances are excessive, mechanical connections to the distant signal are sometimes abandoned, and the signal operated by an electric motor controlled from the tower electrically. This method has come into quite common use since automatic signalling has developed and made familiar the electric semaphore.

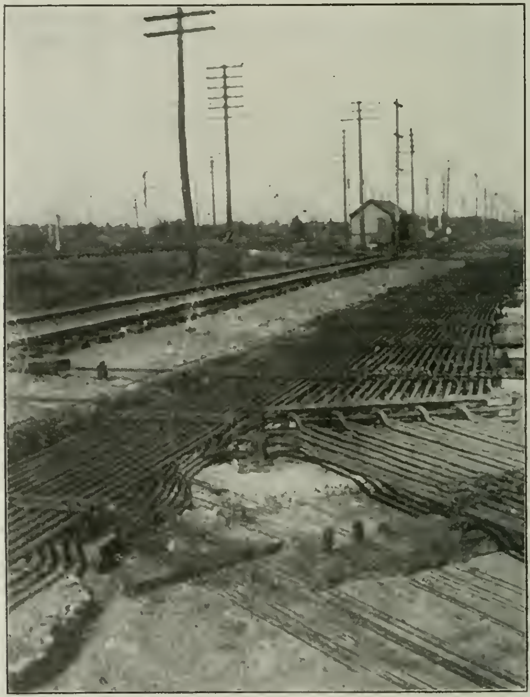


Fig. 6. Pipe and Wire Connections.

Where pipe is used, it consists of 1-inch iron or steel pipe in lengths of 16 feet or more fastened together by the ordinary pipe coupling and also by a plug fitting into the pipe and riveted through. It is supported on carriers every 7 or 8 feet apart which are made up into sets so as to carry the number of pipes running in any one direction. The antifriction carrier now used consists of a roller grooved to fit the pipe and rolling on trunions on a ledge of the pipe carrier side. These sides may be attached to one another so as to build up a carrier for any number of pipes. Present practice secures these carriers to a wooden base which is itself fastened to a concrete block 8 x 12 x 24 inches deep and which is firmly set in the ground. The pipes are placed parallel to the rail and about 4 feet from it, and just below its level, so as not to be interfered with by snow plows, etc. The pipes are placed 2¾-in. center to center, changing at the tower from that spacing to 5 inches, which is the

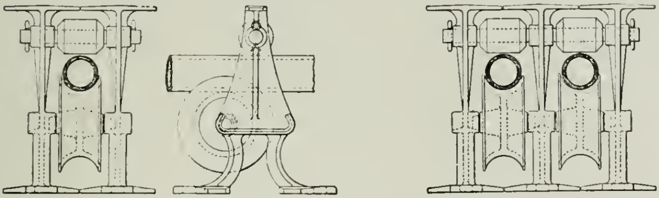


Fig. 7. Pipe Carrier.

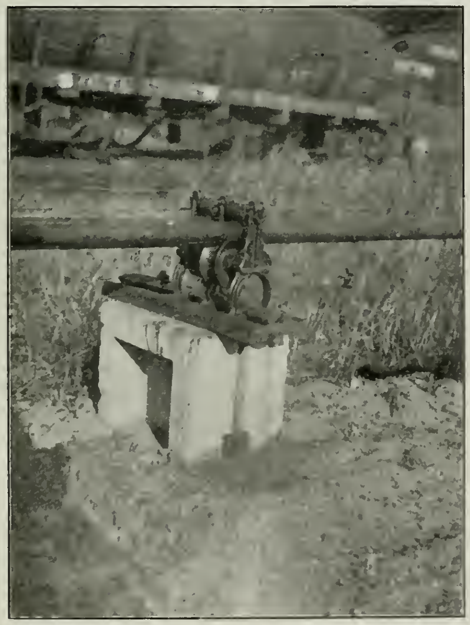


Fig. 8. Carrier in Place.

lever spacing of the machine. The foundations are made up in sizes, the standard being 8-in. wide by 12-in. long on top for a "one way" carrier. Each "way" or size increases in length of foundation block by 2¾-in. In a large machine with many pipes, the space required by the pipe runs is considerable and there are cases where the installation of a mechanical plant had to be given up on account of lack of space in the right of way.

The turns are made by means of "bell cranks" with arms 9 x 9-in. or 11¾ x 11¾-in., the angle of which depends on the angle of the turn. If at right angles, a 90 deg. crank is used, or if a different angle is required the arms of the crank are opened or closed to suit the conditions. This is usually done in the field erection, as most of the turns are right angled, and such cranks alone are carried in stock. Where the deflection is small, radial cranks are used, having a single arm, but with two holes for attaching the the two lines of pipe.

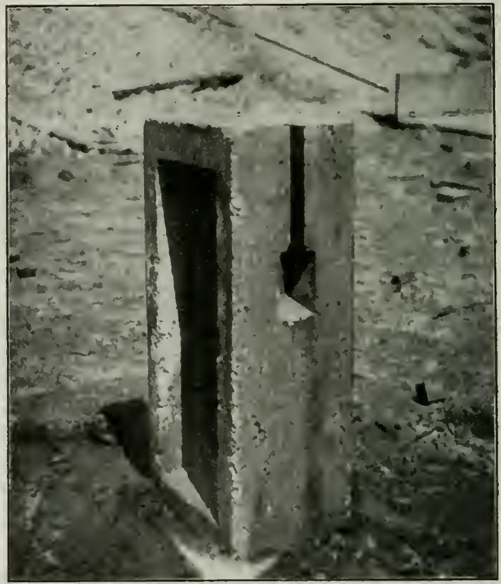


Fig. 9. Concrete Base for Carriers.

As there is a little lost motion in the pipe rollers, since usually the trunions are tapering, the pipe will adjust itself to the ordinary curves, without any special devices. Sometimes this curve is too sharp and deflecting rods are used. These are solid bars of iron introduced into the pipe lines, and moving in a special guide, so that they will transmit the motion around the curve without excessive friction.

Wire lines need much less elaborate supports than the pipe lines. As two wires are used to each signal, the carriers are made in sets of two, or multiples of that number, and consist of small grooved wheels supported by a proper frame. When running along side of pipe lines, these wire supports are placed on the same foundations, but only on every third one. In other places stakes are used, set 21 or 24 feet apart. The turns are made by introducing a piece of chain into the wire line, which is carried around a sheave 8 to 10 inches in diameter.

Expansion and contraction of pipe lines by changes of temperature has to be very carefully considered. This amounts to about 1 inch change in length for each 100 feet, for a change of 100 deg. in temperature. As pipe lines 1,000 feet long are not unusual, it can readily be seen that expansion and contraction must be provided for accurately. The compensating device now used is extremely simple and entirely automatic in its action. It consists of two cranks, one with an interior angle of 60 deg. and the other of 120 deg. and so connected together that a push or pull in the extremity of one crank will give the opposite motion on the other crank. It is plain then that if this device (called a "Lazy Jack") be placed in the center of a line of pipe that the pipe can elongate

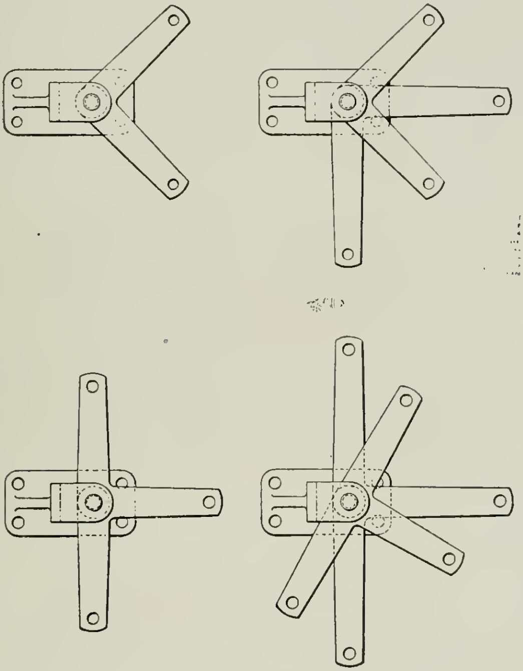


Fig. 10. Bell Cranks.

or contract and that the motion will be taken up by the compensator so that no motion will be perceptible at the extreme ends of the pipe line. Compensators are not usually placed in lines less than 50 feet in length, but in lines over 700 feet long, two are are used, and even three in excessively long lines, the reason being that for long lines the angular motion may be too great, throwing the cranks off the central position, and not leaving room enough for their proper motions, when the lines are operated. In single straight lines of pipes a compensator with longer arms is coming into use, as a greater change of temperature can be provided for, the longer arm giving less angular motion. Compensation can sometimes be provided in part at least by a suitable arrangement of the bell cranks that are required, since they may be set to change the motion, and if this can be done in the middle of the run the compensation is provided for without any other device. This does not usually happen, although there is usually a portion of the line that is compensated by the way the cranks are set. It is often quite a problem where to set the compensators when the lines have many bends and operate more than one function. In such cases it is not always possible to compensate exactly, although it may be close enough for practical purposes. In the case of a "cross-over" operated by one lever, there would be required a compensator between the tower and the near end of the cross-over and another between the two switches. In placing these the length of the cross-runs from the main lines of pipe to the switch must be considered, for in the case of another track intervening this length might be 15 feet or more in length. According to the motion, this length should be added to or substracted from the main run between the first switch and the tower in placing the first compensator and treated in the oppo-

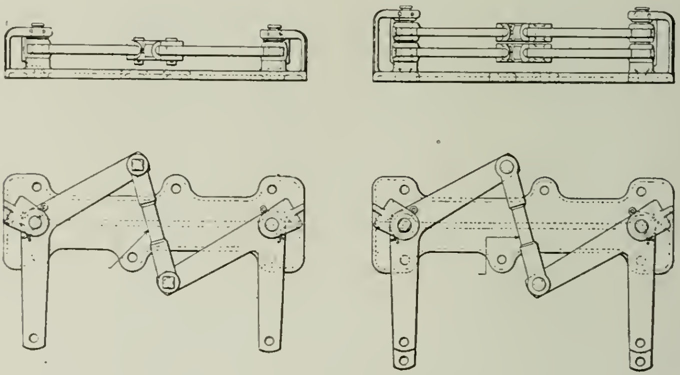


Fig. 11. Compensators for Temperature Changes in Length.

site manner as to the distance between the two ends of the compensator in placing the second compensator.

Expansion and contraction of the wire lines is not so carefully provided for, since it is not so necessary, as usually the functions operated by wire do not require so accurate a transmission of motion. Turnbuckles are provided at the tower in each wire line and also at the signal when the distance is great. Many wire compensators have been invented, but few are in use, none being entirely successful. They depend on weights to take up the slack in the wires, and this is apt to make the signal pull hard. Possibly this difficulty in compensation has as much to do as anything else in leading to the adoption of "power distants." For shorter distances, the temperature does not have enough effect to cause any trouble.

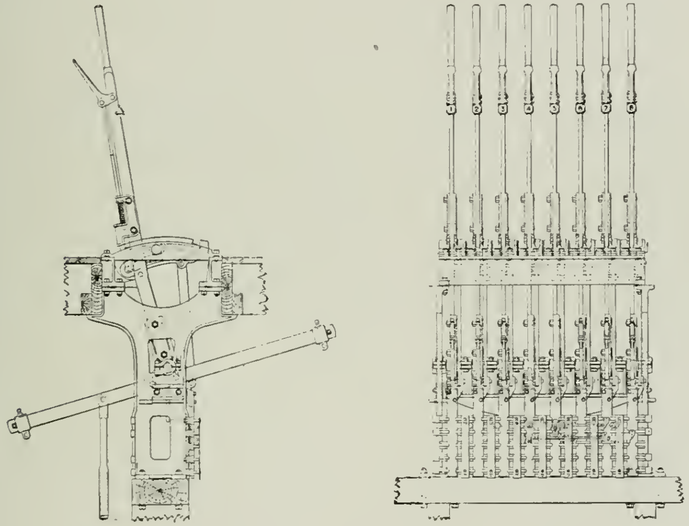


Fig. 12. Interlocking Machine—Vertical Type.

The description of the machine has been left to the last, although it is the most vital part of the whole apparatus since the safety of the whole plant depends on the correct design of this feature. There are two principal types of mechanical machines, the horizontal and vertical. With the former the locking is arranged in a horizontal plane, above the operator's floor, while in the second, the locking is in a vertical plane below the floor. All modern machines (except a few dwarf machines used in special locations) have a latch or preliminary locking, so that the the first operation of throwing the lever which results in unlatching it, locks up all conflicting levers and no other levers are released until the stroke of the lever is completed and it is latched. The locking is actuated by the latch by means of a rocker so adjusted that when the latch is raised the rocker is moved a part of its travel, but its center is so placed in respect to the fulcrum of the lever that it does not move while the lever is being thrown, but only completes its stroke when the latch is dropped behind the catch at the end of the stroke. The latch having then been shifted to the other end of the rocker, its motion is continued in the same direction as it started, thus completing the stroke of the locking. This rocker in some form or other is a feature of all modern mechanical machines. The locking consists of two sets of moving parts, working at right angles to each other and supported in a proper frame, and which is either vertical or horizontal, depending on the type of the machine. The set of bars which move at right angles to the axis of the machine, are connected to the rockers above mentioned, being known as tappets in the vertical machine. In the horizontal type of machine the levers are connected to those bars moving parallel to the axis of the machine. In the smaller machines these are also the same in number as the levers, but above about 40 levers they may be less or even more, depending on the amount of locking required. The right angle series is here called cross-locking. The locking bars in either case is moved by beveled faces of the two series bearing on one another and as force is applied to those of one series, the longitudinal bar is moved also, unless it is held by a locking in some other place. Fig. 13 illustrates the locking of a vertical type of machine. Here the tappets are shown with their jaws ready to connect to the segment of the lever. The pointed pieces fitting into notches on the tappets are known as dogs and are attached to the longitudinal locking bars. On levers 4 and 5 are shown specials, which are for conditional locking as will be noted later.

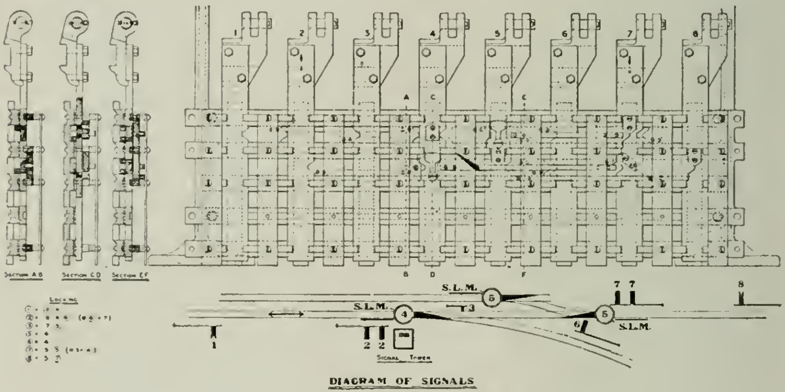


Fig. 13 Details—Vertical Machine.

Machines are made up in multiples of 4, and if a number of levers is required that is not such a multiple, the remaining numbers are left as spare spaces for future changes. Number 1 is usually a distant signal; then follow the home and dwarfs for one direction. The highest number is for the opposing distant signal, and the other signals follow in a decreasing series. The lock and switch levers are in the center, with the spare spaces next to the signals. In big machines the levers are often grouped so that the machine may really be a collection of two or more smaller ones, closely tied together by suitable lockings.

It can easily be understood that the locking is an important part of the whole plant, and great care is taken in properly making out the locking sheet, which is merely a table taking the lever numbers in rotation and showing what each lever locks when it is reversed. In making out this locking sheet all levers are assumed to be normal, that is back in the frame away from the operator. "No. 1" is first considered. As this is usually a "distant," it must lock all home signals that it governs reversed; that is, the home signal levers must be pulled over towards the operator, and thus "clearing" the signal before the distant signal can be "cleared," since, as above described, a clear distant signal indicates a clear route through the limits of the interlocking. The home signal locks, first, all opposing signals in the stop position, and must lock all switches in the proper position for the route controlled by it. The dwarfs do the same, except they are not controlled by a distant signal. The lock levers lock the switches they control in either position usually, the signal picking out the proper position of the switch, with derails; the locks lock it one way only, reversed. Usually, locking is introduced between the switch levers, so that, even should the signal be disobeyed, trains would have a safe route or be derailed before having a collision with another train. The amount of locking between switches depends on the engineer's preferences and on the work to be done. At a very busy place much of the locking between switches is omitted, so as to save unnecessary movements by the operator. Of course, when crossings are involved and derails are introduced to avoid collisions, the locking between opposing derails must be absolute. It is often necessary to introduce special or conditional locking. To make the locking between various functions positive would often tie up the plant so it could not be worked. These specials are introduced usually on the switch levers, and are so arranged that the locking is not accomplished unless that switch is in its proper position. A case of cross-over in a double track is a simple example. There the signals on one track should not lock the functions on the other track unless the cross-over is set so that trains may pass over. This requires a "special" on the cross-over lever.

After the locking sheet is prepared, the "dog chart" is made. This is a sort of conventional plan of the locking, and shows quite plainly how the locking is to be arranged, and is really the working drawing from which the shop men construct the machine. As it is more or less a collection of symbols, it is difficult to be understood except by one familiar with such matters. While requiring considerable skill to properly arrange it so that the locking will be most effectively and economically arranged, it does not require quite the same skill and knowledge as to make out the locking sheet.

When the work to be done by an inter-locking plant is large, the distances great, or quick work is desired, a power machine is used. Generally, until a mechanical machine reaches about 40 levers, it does not pay to consider any form of a power machine, since they are more expensive both to install and to operate, and also requiring more experienced help to maintain. When a machine is above the size mentioned, it is a question whether two men will not be required on a shift, although if not a busy place one man alone can handle a much larger plant. If the services of one or two men can be saved, this saving in wages will pay interest on a large investment for a power plant. The saving of men results from less physical effort being required and also because the machine will be smaller, for often a big machine may have not over half the levers of a mechanical machine to do corresponding work.

With a power plant, the same principles apply as in a manual one. The signals are located the same, have the same names, and give the same indications. At the switches we find the detector bars of the same design and often using exactly the same fittings. The only difference, then, is the means of transmitting the power from the machine to the function to be operated. There are now three classes of power machines in successful operation: the "electro-pneumatic," the "low-pressure pneumatic," and the "all-electric." In the first, compressed air is the power, but electricity is used to control the operating valves, by means of a proper system of wiring between the tower and the switches or signals. The air pressure varies from 60 to 80 pounds per square inch, and the supply is kept up usually by an independent plant, or by taking air under pressure from some other supply, such as is usually found at a railway terminal, where power plants have their greatest field. With the low-pressure plant the use of electricity is dispensed with, but a double system of pressures is used. The working pressure is about 16 pounds, and the valves admitting the operating air to the various cylinders are controlled by a separate system of pipes, which convey the air under a pressure of 5 or 6 pounds only. The air for power can be obtained from the usual station supply, using a reducing valve if necessary, or an independent supply can be maintained at the plant by the use of steam, gasolene or electric compressors. The all-electric machines use electricity only, and the direct operating current of 110 volts passes from the machine to the switch or signal, where is located a motor of suitable design for the work to be done. The power is usually generated by a gasolene engine belted to a small dynamo, used in connection with a storage battery of 55 cells. Electric power can also be taken from a city service, using, if necessary, a suitable transformer.

An important adjunct of all power plants is the "indications." The operator in the tower of a mechanical plant can tell by the effort to pull the levers pretty accurately whether it is doing its work properly or not; certainly there is no mistake when a connection is broken, or stuck, or a switch point held open by some obstruction, which would also be detected by the facing point lock. With the power machine, however, there is no way to judge by the action of the lever what has been done. Therefore, the "indication" is provided which tells the tower man that the work has been accomplished and he can take advantage of it. It has been found necessary that something more than a mere visual or audible notification was necessary, so the scheme was developed of preventing the lever from completing its stroke and releasing the locking until the function had indicated. An automatic indication has been developed, so that on receipt of the indication the stroke of the lever is automatically completed. Without this, the operator must go over his levers a second time, putting them "home" as fast as released. On a large and busy machine this consumes valuable time. The "indication" is given in various ways under the different systems. The all-electric and the electro-pneumatic using electricity and the low-pressure pneumatic using air. Careful provision has to be made so that a false indication can not be received. Signals are usually indicated in the normal position only.

A switch and lock movement is used with all power plants, since there is ample power and the movement can be so designed as to be as safe as any other device. The only limit to the load is that of correct operation of the plant, since it requires no more effort to move the lever regardless of the load. With a ladder extending across a switch yard with a series of slips, the number of levers in a power plant may be reduced by 75 per cent. There is no difficulty in operating opposite ends of two adjacent slips together with movable point frogs and all the bars on a lever. With a manual machine this would require six levers and under such circumstances the saving in time can be easily imagined.

While it is usual to speak of a power machine having levers, it does not in fact, have levers, but the valves or electrical contacts are actuated by a handle of suitable design. The locking is the same as the mechanical, but of lighter design, since it does not have to stand the same strain. As the levers are usually about half the distance apart and fewer in number, the machine can be set in less space, requiring a less expensive tower and foundation.

The tower in any plant varies in design with every road. Usually they are 12 to 15 feet in width, the large horizontal machines needing even more space than this and of a length sufficient for the machine and still have room for the operator's table. etc. The operator is on the second floor, about 15 feet above the rail. Local conditions sometimes requires a higher tower, or a lower one may be used. Small machines are at times put in the station telegraph office. At some places it is not necessary to have a man in attendance all the time, but the signals are left "clear" for the important road. When anything on the secondary line desires to cross, a trainman enters the cabin, closes the route on the main line and sets up his own route. While doing this he locks himself in the cabin automatically and must remain there until he is through, and the signals are restored to their normal position for the main track.

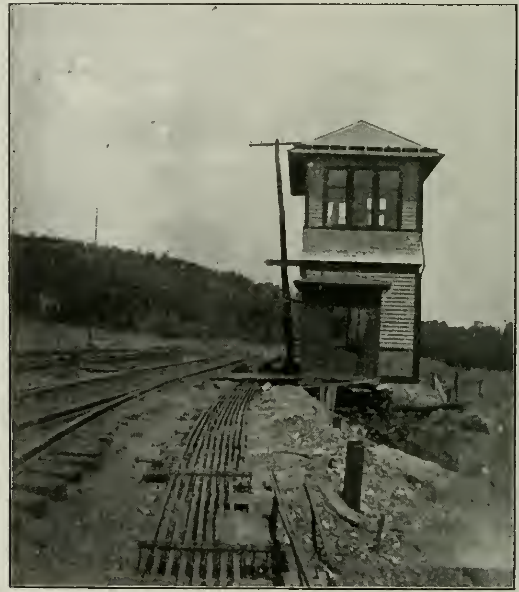


Fig. 14. Signal Tower with Pipe Runs.

The lower part of the tower is used for the lead out connections in mechanical work and some times, but not preferably, as a lamp room, or for such other purposes as may be desired. In power plants the lower story may be used for the power generating outfit, and for storage batteries.

In designing an interlocking system the first requisite is a correct track plan. Unfortunately this is not always obtainable, so that the plant has to be laid out on what plans can be found. All changes of tracks and future changes should be carefully considered, but it is every signal engineer's experience that this is too often left until plans are drawn up or even the contract let. Generally two or more roads are concerned in a plant, and the difficulty of getting an agreement increases with the number of roads interested. After the plan is obtained and tower located, it is signaled up in accordance with the principles above stated. Careful consideration must be given to the train movement, and the operating departments must be consulted. Each road involved has its own specifications and these must be known and taken into consideration.

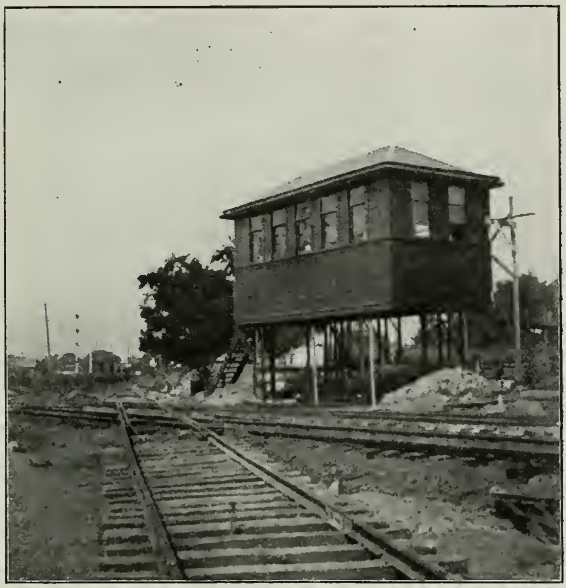


Fig. 15. Signal Tower at Crossing.

The machine is usually so placed that the operator faces the main track. The plan is numbered, beginning at the operator's left. As above stated, the signals are at the ends. If wire-connected, the arrangement does not make very much difference; but the convenience of the operator must be considered. In numbering the locks and switches, some care must be taken to so arrange them that the connections will be in good shape, both as to appearance and easy working. There are a great many points to be considered, so that it is difficult to give any set rules; but the engineer must draw on his experience and knowledge of conditions to be met. One lever is now allowed to each signal, the use of selectors by which two signals were operated by one lever being now practically abandoned. Usually no more than two bars or two switches are allowed for a lever. One switch and lock movement is a fair load for the operator. The distance has something to do with the load, for if over 1,000 feet away loads must be lightened, but it is not very good practice to work switches much over that distance.

Block signaling can be almost considered as a separate branch of the art, although it is always handled, in its more complete forms at least, by the signal department. The spacing or blocking of trains at first was accomplished by the time interval; that is, one train must not leave a given point until the preceeding train has been gone 10 or 15 minutes. This system, while a great advance over no blocking, has one fatal defect, and that is, should the first train run slowly or break down, the second train might easily overtake it, even should the flagman be alert. While the "time interval" system has its uses, the "space interval" is now the recognized system. It is not difficult to introduce the block system. By equipping each telegraph office with semaphores and setting aside a telegraph wire for block work alone, all the requisites are found. Of course, it all depends on the operator; but so much safety can be secured by so little expense that it is strange that railroads do not adopt the "telegraph block" much more rapidly than they are doing. For telegraph block work a double arm semaphore is used, with one arm on each side of the post and pointing in opposite directions for trains proceeding in either direction. These signals, which can also be used for train order signals, are usually placed near the telegraph office and are operated by a small lever, or even a simple cord, within easy reach of the operator's desk. Naturally, the method of operation varies. Perhaps the most common way is to have the signal at danger, except when a train is actually approaching, when it is "cleared," provided there is no train in the block ahead. Where traffic is heavy, permissive blocking is resorted to, by which a train is admitted to a block when it is occupied by a preceding train; but, by cautioning the train crew that it has not a clear block. This is usually done by some kind of a card to be filled out by the operator to suit the local conditions. A record sheet is usually kept at each station to show the time of departure of each train and its clearance at the end of the block.

With many trains and numerous other duties to perform, it is not easy for the operator to give sufficient time to the blocking of trains, so that it is easy for him to carelessly or through misunderstanding to give a "clear" signal when the block is occupied. A simple and effective remedy is found in the track electric circuit by which the trains automatically control the block. While not usually found in connection with a simple telegraph block, the track circuit will be here described: Each rail is bonded electrically around the joints similar to the way a trolly track is treated but using a much lighter bond, and iron instead of copper wire is used. In this way

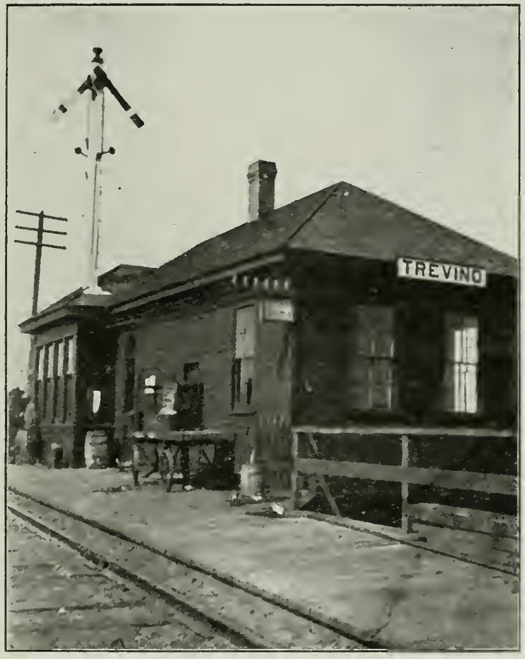


Fig. 16. Telegraph Block Signal.

each rail becomes an electric conductor. At one end, a battery is introduced, generally of two cells, of blue-stone, or of a gravity type being used, and placed in a wooden or iron chute, buried in the ground, to keep from freezing, and with one pole connected to each rail. At the other end of the circuit, a "relay" is introduced between the rails so that the current must flow through the coils. The circuits are limited by means of insulated joints; that is in place of the ordinary angle splice bars connecting the rail ends, a special device is used with fibre parts, so arranged as to give insulation of one rail from another. Sometimes merely wooden blocks are used, with fibre end parts between the rail joints, but these are difficult to maintain and have been displaced by a more durable joint. Since the rails are not insulated from the ties or ballast, an electric current of low potential must be used in the track circuit and hence the circuit cannot be too long, but must be divided into sections. While they may be operated a mile or more, generally a less length is found to give the best results. From the relay, wires carrying a heavier current are run to the device controlling the signal. All diverging switches must be insulated to prevent crosses and also to prevent them from being opened without displaying a stop signal.

As business increases especially with a double track road, it may become necessary to introduce the manual controlled block. Here are found the block signals and the track circuit, but the operator is not free to clear the signal when he thinks he should, but by means of the track circuit the train itself controls the block, by the fact that the wheels and axles of the train form a better path for the track circuit current than the relay does, so that the latter is demagnetized, and opening the controlling circuit. With a continuous track circuit all that may be necessary is an electric slot in the signal so that when the circuit is broken, the connection between the wire and the signal is also broken, the slot consisting of a catch actuated by a magnet. When it is not desired to use a continuous track circuit, quite a complicated device is necessary at each station to fulfill all the conditions, but it has been successfully done.

The interlocking plants can be introduced into the block system by considering the home signal as a block signal also, or even introducing a separate block or advance signal. The latter, if properly located, increases the capacity of the system, since a train may wait and allow another train also to come up to the home signal behind it. Where there is a junction this is quite necessary, in order to get trains over the road promptly. Many roads are now interlocking not only their crossings and junctions, but the sidings and crossovers as well. This, forming part of the manual block with all remote switches electrically locked, is about as perfect protection as can be given to-day, or as is needed.

In many cases it is necessary to introduce the block system without the interlocking, on account of lack of money or time. Then the automatic signal comes in use. In its present form, this is a regular semaphore operated by gas or an electric motor. In either case, this is controlled by the track circuit. They can be introduced between interlockings to shorten up a block when it is not desired to add to the expense of maintaining a tower for blocking alone. In a system of automatics, if they are spaced not over a mile apart each signal has two arms, the distant signal for the next home being in the front, so that a train receives an indication for two blocks ahead. If both blocks are "clear," both the home and distant are clear. If only one block is clear, then the home signal only clears, and the distant signal remains at caution. Where the blocks are long, it is better to place the distants on separate posts, a suitable distance in the rear of its home. It can easily be understood that there must be quite a complication of circuits to take care of all the conditions that arise, especially when it is considered that an indication should be placed at each switch to show when a train approaches, so that it may not be opened.

The location of a series of automatic signals is an important matter, needing careful attention of the operating department, as well as the signal engineer. While at an interlocking the signals are practically all located by fixed rules, automatic signals must be so placed as to give the best results. The grades, stations, water-tanks, etc., must all be considered. The question of passing sidings is an important one, and it is difficult to locate signals in such places so as to give the proper indications without too great complications, and hardly any two engineers will agree as to the arrangement, which is to be expected, as hardly two roads use their passing sidings in the same way. A very satisfactory plan where lap sidings are used—that is, for single-track roads where a separate siding is used for trains in each direction, with the ends overlapping each other—is to interlock these two ends and control the far or outgoing ends by electric locks. The advance or block signal may then be placed nearly to the end of the siding, and so arranged that when a train is passing out it is held at danger.

Automatic signals are operated on the normal "danger" or normal "clear" plan, each of which has its advocates among the signal engineers of the country, and each has strong arguments for its use. By analogy to interlocking plants where the signals are normally at "stop," the first method has a strong argument in its favor, and perhaps is what has given that arrangement so strong a foothold. Lately the normal "clear" has made much headway, and while it apparently violates the first principle of signaling, viz.: that every failure must be at the stop position, yet it is not proven that it will remain in the "clear" position if there be a failure any more certainly than the normal "danger." It has in its favor less complicated circuits. One difficulty with the normal danger is the long distance back of it, that the clearing track circuit must be placed, especially with high-speed trains. If there be a distant signal, this should not properly be "cleared" until after its "home" has cleared, which still further increases the time, and hence the distance, in the rear of the point at which the train clears the home signal.

The question of signaling has by no means been exhausted in this paper, but what has been said it is hoped will give some idea of its importance to modern railways, and it is hoped that these remarks may lead to further interest in the matter, and that it may give the members of the Society a glimpse of some of the difficulties encountered by the signal engineer.

D. C. Morgan, M. W. S. E. (by letter)—The paper prepared by Mr. G. E. Ellis on "Railroad Signaling" omits at the outset one of the essential functions of signaling appliances. It may be regarded primarily that safety is the first essential of signal installations, but the facility these devices afford in the conduct of transportation is an element of very great importance and gives a broader meaning and a broader effect as regards both function and cost than can be attributed to the individual appliance. The field of usefulness of the signal engineer is largely confined to the details of the devices, while, to the operating official, it involves the effectiveness of the devices from the standpoint of safety and the facility their installation affords in conducting transportation.

The preparation necessary to completely fulfill the purposes of signaling involves many expenses which do not appear as a part of the cost of the device. It does not seem that this is clearly understood, but it is, nevertheless, true that the cost of appliances themselves as related to the cost of preparation necessary to their successful operation is comparatively small.

One of the criticisms heard of American practice in signaling may be termed lack of permanency; that is, the dominating factor does not lead to installations of a stable or permanent character. In this respect, great difference is found in a comparison of American and European devices, the latter being heavier, and, in many ways, designed to better withstand the elements and the wear and tear to which they are subjected; the result being that, while the initial cost of our devices is less, the relative life is also less and the cost of maintenance is greater.

It is not to be presumed, however, that these facts indicate lack of foresight on our part. In fact, there are elements which would point to the belief that our practice is really the best under the circumstances effecting railway operations in America. This would lead us to consider the great undertakings of grade and alignment revisions now going on throughout the country, and to the ever-changing conditions of commercial development, all of which indicate that railway managements appreciate that our railways have not yet reached a state of physical perfection such as to enable the most economical handling of traffic, and are also quite unable to foresee what elements will effect our commercial development, and the consequent volume of traffic.

With these important factors to consider, it is manifest that what may be considered an efficient installation to-day is not unlikely to be rendered useless in a decade. Not only these facts, but also the rapid development and improvement of the devices themselves lead us to be cautious lest we find shortly that the appliances we have taken such pains to install are entirely behind the times.

The ingenuity and skill which is being constantly brought to bear to improve the present appliances, and the fact that they *are* continually being improved, shows conclusively that we have not reached a state of perfection.

There have been some suggestions made that a National Law should be enacted, giving to the National Government the power to control safety appliance of this character. It may be that the question of "States Rights" has been effectively disposed of in some respects, but it does not appear clear that the United States Government has the right to interfere with the sovereignity of the state in controlling safety appliances until it shall first take from the state its right to proscribe maximum rates of freights and fares within its limits, and annul the enforcement of other laws pertaining to railways, which, at this time, seem to come clearly within the prerogative of the state.

I present these points in the hope that they may lead to some discussion of this phase of the subject, it being my belief that, in a very large measure, can the railway companies be relied upon to voluntarily install such appliances as are necessary to safeguard the traveling public.

FLEXURE OF REINFORCED CONCRETE BEAMS.

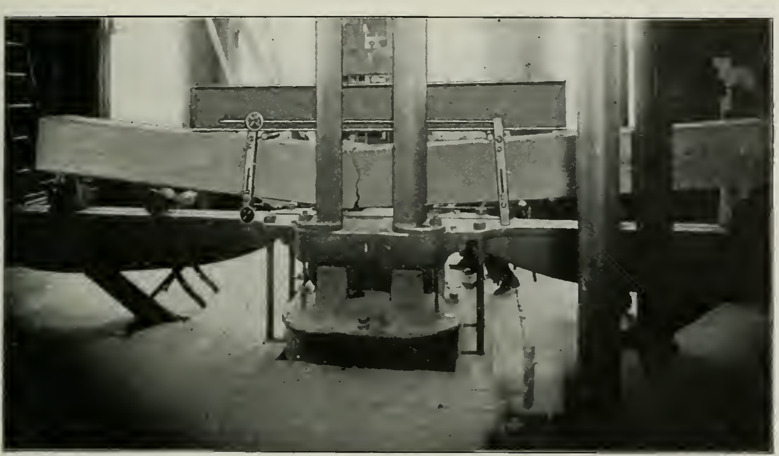
By Arthur N. Talbot, M. W. S. E.

Professor of Municipal and Sanitary Engineering, in charge of Theoretical and Applied Mechanics, University of Illinois.

It is not strange that a diversity of views and opinions exists concerning the action of a combination of steel and concrete and the proper method of calculating the strength of reinforced concrete beams. The method of construction is relatively new. The properties of concrete are not as regular nor as well defined as those of structural steel. Different investigators have worked under different conditions and for different ends. The assumptions sometimes made in deriving theories have been found not to be supported by experimental data. Certain properties are defined and used differently by different investigators. Conflicting opinions are held on the effect of shear, the appearance of cracks, the conditions for maximum strength, and the distribution of stresses. It is too much to expect that the final status of the design of reinforced concrete beams will be established at once, and any contribution to our knowledge of this subject may be useful in fixing principles and settling differences.

It is the purpose here to present a summary of tests of reinforced concrete beams made in the Laboratory of Applied Mechanics of the University of Illinois, and briefly to discuss some of the analytical phases of the resistance of such beams to flexure. These tests were planned not to cover the field of experiment, but rather to discover the effect of certain conditions and to uncover the field for future investigation. The number of variable elements was made as small as possible. For example, the effect of shearing stresses was considered only so as to avoid failure by shear. Some of the differences in conditions were put out as feelers rather than with the expectation of making final determinations.

In planning the series the following matters were kept in mind, as being important elements, not fully accepted by investigators: 1, The general action of the beam during the progress of loading and the method of its final failure; 2, The amount and character of the deformations in the steel reinforcement and in the concrete, and so far as possible the amount of the stresses therewith developed; 3, The effect of the form of reinforcing bar; 4, The effect of the amount of reinforcement; 5, The position of the neutral axis and the measure of the resisting moment of the beam. Experimental work was also done on the adhesive bond of steel and concrete and on the coefficient (modulus) of elasticity of concrete in tension and compression as having a bearing on the flexural action of beams.



View of Beam After Completion of Test.

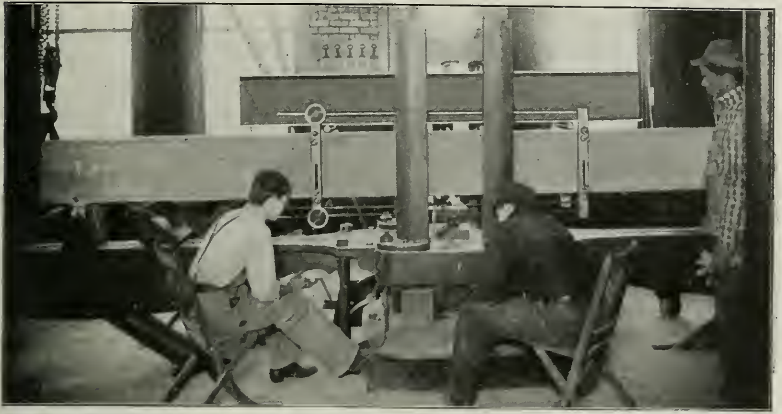
Limitations of floor space reduced the number of beams for the several kinds and amounts of reinforcement below what had been planned, but the general action and behavior of all the beams was so similar that the writer is disposed to place more reliance on the results of individual beams than he generally does in experimental work, and particularly more than can be placed on small concrete beams. Twenty-two reinforced concrete beams were tested. Their dimensions were 15 feet 4 inches length, 12 inches width, and 13½ inches depth. The center of the metal reforcement was placed 12 inches below the top of the beam. In some of the beams with a large amount of reinforcement part of the rods were inclined or bent diagonally upward from the third points of the beam to a level above the middle of the beam at its ends with a view of obviating possibilities of failure by shearing. The span used was 14 feet. The load was applied equally at two points, the third points of the span. This loading does not differ greatly in maximum bending moment and in the shear at the ends from the conditions for uniform loading and has the advantage for the measurement of deformations that the stresses except for the dead load are equal at all points between the two load points. The bending moment of the applied load is ⅙ W l for the middle third of the beam.

Chicago AA Portland cement bought in the open market was used. 1 to 3 mortar gave 233 pounds in 7 days and 400 pounds in 60 days. The sand was fairly clean and well graded in size and contained 29 per cent voids. The stone was crushed limestone and ranged between ¼ inch and 1½ inches in size, and contained 44 per cent voids. The concrete was by loose volume 1 cement, 3 sand, 6 stone. Concrete beams having the dimensions of the reinforced concrete beams gave a modulus of rupture of 343 pounds per square inch, counting both the applied load and the weight of the beam. 6-inch concrete cubes gave an average compressive strength of 2,030 pounds per square inch at 60 days.

Collection of Beams.

For the reinforcement plain round rods, plain square rods, Johnson corrugated bars, Thacher, Ransome and Kahn bars were used. The amount of reinforcement varied from 0.6 square inch of metal to 2.4 square inches, or 0.42 per cent to 1 ⅔ per cent of the area of concrete above the center of reinforcement. The yield point of the plain bars and of the Kahn and Thacher bars was between 32,000 and 35,000 pounds per square inch. The yield point of the Johnson bars was between 55,000, and 60,000 pounds per square inch. The yield point of the Ransome bars, not determined, was also high.

The beams were made directly on a concrete floor, except that a strip of building paper was placed under them, and they were not disturbed from this position until taken to the testing machine. The beams were tested at 60 days' age, the greatest variation from this being 3 days. This age was sufficient to reduce the variations in properties of the concrete due to differences in moisture and atmospheric conditions to a relatively small amount. Care was taken to have the work of mixing done uniformly, and the general appearance and behavior of the concrete was quite uniform.



Usual Arrangement of Apparatus.

The tests were made on an Olsen testing machine of 200,000 pounds capacity, with beam attachment. The extensometer device was carefully planned and calibrated and it is believed that the measurements are trustworthy. Each frame of the extensometer device was attached to the beam by two pairs of screws, one pair generally being placed against the sides of the beam 1 ¼ inches below the top of the beam, and the other pair 1 ¼ inches above the bottom of the beam. The gauge length was generally about 61 inches. Four extensometers, modified forms of the Johnson instrument, were used, their position being above and below the contact screws, but directly in line with them. They read to $\frac{1}{10000}$-inch. The beams rested on rocking supports, allowing longitudinal adjustment with elongation of lower side of beam and deflection of beam. At the two load points 2-inch steel cylindrical pins were placed and the I-beam through which the load was applied rested on these. With the appliances used an end compression estimated to be equal to, say, 3 per cent of the compressive stresses in the beam would be necessary before longitudinal adjustment would be made. In other words, the tension was relieved by this amount. Bearing plates with a layer of plaster of paris were placed above and below the beam to give uniform distribution across the width of the beam.

Diagrams—Several typical load-deformation diagrams are given showing the relation between the applied load as ordinates (not including the weight of the beam which has already stressed the fibers when the instrument is read at zero load) and the deformation per unit of length as abscissas. From the readings of the extensometers (which it will be remembered were above and below the beam and hence gave magnified values) the shortening of the upper surface of the beam was calculated and this shortening was divided by the gauge length, which was in the neighborhood of 61 inches. This gives the compressive deformation per unit of length marked "Upper fiber" on the diagrams. Similarly the elongation of the beam at the level of the center of the steel reinforcement was calculated, and this elongation divided by the gauge length is marked "Steel" on the diagram. The calculations are based on the assumptions that a plane section before bending remains a plane section after bending and that the steel elongates the same as the concrete at the same depth. Generally the extensometers were taken off at the maximum load. The deflections at the middle of the length of the beam are also shown, a second scale of abscissas being used for this. The upper part of the diagrams gives the successive positions of the neutral axis obtained under the same assumptions as above. The ordinates denote this position in per cent of the distance from the top of the beam to the center of steel reinforcement for the applied loads given on the scale of abscissas.

Using Two Extensometers for Testing Conservation of Plane Section.

TABLE—The table gives the stresses found in the steel reinforcement and the resisting moment developed by the steel at certain loads, as calculated by the methods and assumptions here described. The column "Load considered" is the applied load somewhat below the maximum load and for which elongations and shortenings are definitely known and hence is the load used in the calculations for the succeeding columns. The stress in steel is based upon the ob-

TABLE.

Beam No.	Amt. and Kind of Reinforcement.	Area of Metal sq. in.	Extensometer Gauge Length, inches.	Maximum Load, pounds.	Load Considered, pounds.	Total Elongation of Steel, inches.	Stress in Steel, lbs. per sq. in.	m Inches	Moment Arm $d-\frac{4}{11}m$, inches	Resisting Moment M_R, in.-lbs.	Bending Moment M_B, in.-lbs.	$\frac{M_R}{M_B}$	Estimated Total Bending Moment M_B', in.-lbs.	$\frac{M_R}{M_B'}$
21	3–½ in. Plain Round	.59	60.5	9000	8000	.0665	32900	4.00	10.55	204000	224000	.91	261000	.78
19	3–½ in. " "	.59	60.5	9200	9200	.0755	37400	4.50	10.36	228000	257600	.885	294600	.775
16	3–½ in. Plain Square	.75	60.75	9900	9900	.065	32100	4.50	10.36	250000	277200	.90	313200	.80
17	3–½ in. " "	.75	60.5	10000	9500	.059	29300	4.25	10.45	229000	266000	.86	302000	.76
27	4–¾ in. " "	2.25	56.75	26900	25000	.066	34900	6.38	9.68	760000	700000	1.085	725500	1.05
9	3–½ in. Ransome	.75	60.87	22800	18000	.142	70000	3.75	10.64	559000	504000	1.11	540000	1.035
15	3–¾ in. Thacher	1.20	61.25	18400	15500	.0715	35000	4.75	10.27	431000	434000	.99	466000	.925
10	3–¾ in. "	1.20	60.87	16600	14500	.065	32000	4.75	10.27	394000	406000	.97	438000	.90
22	3–¾ in. Kahn	2.40	56.75	24400	22000	.064	33800	7.87	9.14	743000	616000	1.205	641000	1.16
4	5–½ in. "	2.00	61.25	23000	21000	.069	33800	5.62	9.96	673000	588000	1.14	615000	1.095
14	4–½ in. "	1.60	61.5	17200	17000	.062	30200	5.50	10.00	483000	476000	1.015	505500	.955
5	3–½ in. "	1.20	61.25	15000	13000	.0625	30600	5.00	10.18	374000	364000	1.03	396000	.945
28	6–¾ in. Johnson	2.19	60.25	34300	31000	.101	50300	7.25	9.36	1030000	868000	1.185	893500	1.15
13	7–½ in. "	1.40	60.62	29000	27500	.111	54100	5.75	9.91	751000	770000	.975	800500	.94
20	5–½ in. "	1.00	60.75	20900	20000	.132	65200	5.50	10.00	652000	560000	1.165	593500	1.10
2	5–½ in. "	1.00	60.75	20600	19000	.119	58800	4.75	10.27	604000	532000	1.135	565500	1.07
7	3–½ in. "	.60	60.5	14000	13000	.1175	58300	3.75	10.64	372000	364000	1.02	401000	.925
3	–½ in. "	.60	60.75	14000	12000	.1065	52600	3.63	10.68	336000	336000	1.00	373000	.90

served deformations, using the modulus of elasticity found for the naked steel bars. m is the distance of the neutral axis below the top of the beam found as explained hereafter. The position of the center of gravity or centroid of the compressive stresses is taken in the calculations to be four-elevenths of the distance down to the neutral axis. This position is the result of analysis which cannot be given here and is close to the usual assumptions which take into account the varying relation between stress and deformation in concrete; nor will the difference between this position and that resulting from the assumption of a constant modulus of elasticity give a serious error. The moment of resistance of the beam, neglecting tension in the concrete, is found by multiplying the tension in the steel as found from the the deformation and modulus of elasticity by the distance from the center of the steel to the centroid of the compressive stresses in the concrete, $d - \frac{4}{11}m$, where d is the vertical distance from the top of the beam to the center of the steel reinforcement. This is readily seen to give the resisting moment, or if not reference may be made to the discussion on resisting moment given further on. The column $\frac{M_R}{M_B}$ gives the ratio of the resisting moment calculated, as shown above, to the bending moment, at any point between the loads. The last column gives the same ratio with the bending moment augmented by the estimated proportion of the weight of the beam which the broken tensile fibers of the concrete have transferred to the steel. Further uses of the table will be apparent in the further references to it.

General Phenomena of the Tests—A study of the tests and of the load-deformation diagrams shows four stages of flexure during the progress of the loading. Through the first stage, as the load is applied, the action of the beam and the changes in deformations of upper and lower fibers are similar to those in plain concrete beams, modified of course by the metal reinforcement; and the resistance of the tensile stresses of the concrete is plainly apparent. When a load of about 4,000 pounds for $\frac{4}{10}$ per cent reinforcement and of about 6,000 pounds for 1.5 per cent reinforcement is reached (equivalent to about 250 pounds per square inch tension in the extreme fiber of the concrete for its share of the applied load, and 350 pounds per square inch when the weight is considered), the second stage begins. The steel elongates more rapidly with the application of the loading, there is a similar increase in the compression of the concrete, the neutral axis rises, and there is a marked change in the character of the load-deformation diagram. While no cracks are visible to the naked eye at this second stage, it is evident that much of the tensional value of the concrete has been lost. This stage may be called the readjustment stage. During the third stage the increments of the deformation of the steel are closely proportional to the increments of the loads, as shown by the straight line of the load-deformation diagram, and the compressive deformations generally approximate a straight line. During this stage vertical cracks appear, generally quite numerous and well distributed along the middle third of the length of the beam, and grow in width; but this appearance is not accompanied by any change in the character of the load-deformation diagram. This stage continues until a point at or near the maximum load is reached, except with those beams having an excess of reinforcement. The last, or stage of failure, begins at or near the maximum load. The beam deflects more and more, the load required to balance the scale beam becoming less and less. The steel stretches rapidly, the neutral axis changes position, and there is a more rapid compression of the upper fiber of the concrete, until finally the concrete crushes out at the top of the beam at a load below the maximum and after the steel has stretched considerably beyond its yield point. The diagrams of Beams 14, 16, 17 and 19 show deformations beyond the maximum load. The exception to the above is in beams having more than 1 per cent of metal of 55,000 pounds per square inch elastic limit or more than 1 ½ per cent of 33,000 pounds per square inch elastic limit. In such beams the concrete at the top of the beam fails by crushing before the elastic limit of the steel is reached. In all the other beams the full compressive strength of the concrete was not developed at the maximum load. It may be noted that the deflection curve does not change its character until after the crook of the deformation diagram is well begun and until after the yield point of the metal is passed, a result to be expected.

MAXIMUM LOAD AT YIELD POINT OF METAL—The observed deformations show that for beams not having an excess of metal (say not more than 1 per cent of reinforcement with steel of 55,000 pounds per square inch elastic limit nor more than 1 ½ per cent with steel 33,000 per square inch elastic limit for the concrete used in this work) the maximum load is nearly reached when the steel is stressed up to its yield point, and the load at the yield point of the metal may properly be taken as the ultimate strength of the beam. Actually, the maximum load is somewhat greater than this, averaging about 6 per cent more for all the beams and in one case reaching 15 per cent more than the load at the yield point of the metal. The table shows that for the points chosen, which are just below the yield point of the metal and somewhat below the maximum load, the resisting moment for the steel (calculated by multiplying the stress found in the steel by the distance to an assumed centroid of the compressive stresses of the concrete, and thus taking into account an equal amount of compression) is in general approximately equal to the bending moment due to the load, and hence that the moment of the tensile stresses of the concrete is negligible. The exceptions to this are (1) in beams with light reinforcement and low elastic limit metal, in which case the moment of tensile stresses in the concrete and also added stress in the steel at the vertical cracks may possibly account for the deficiency in the calculated resisting moment; and (2) in beams with an excess of metal, in which case the centroid of the compressive stresses, after the stresses approach the ultimate strength of the concrete, is probably lower than the position assumed, and hence the real moment will be less than the value here given. However, it seems that within the usual limits of reinforcement (say from ½ per cent to 1 ½ per cent reinforcement with steel of 33,000 pounds per square inch elastic limit and to 1 per cent with steel of 55,000 pounds per square inch elastic limit for this concrete) the calculated moment of the steel about the centroid of the compressive stresses is for the maximum load approximately equivalent to the bending moment, and no consideration need be made of tension in the concrete. These limits of 1 and 1 ½ per cent are given as tentative limits and not of course as final determinations.

STRESSES IN SECOND AND THIRD STAGES—Several interesting characteristics are apparent in the second and third stages. In the steel diagram the crook or elbow of the second stage and the reversal of curvature just after are characteristic. The increased elongation of the steel just after the crook seems to indicate that the concrete has broken in tension through a part of the depth of the beam, and that a part of the weight of the beam which had been taken by the tension in the concrete has now been transferred to make added tension in the steel. A line parallel to the load-deformation line above the elbow and tangent to the elbow lies above this line a distance equal to the amount of added load which may be expected from the beam. It is quite noticeable that during the third stage the load-deformation diagram is a straight line and that the increment of stress in the steel calculated on the assumptions heretofore made, and hence its moment, is proportional to the increment of the load, though the stress in the steel is not proportional to the load. In fact, as may be seen by a study of the results, this increment in the resisting moment of the steel about the assumed centroid of compressive stresses is greater than the increment of bending moment of load; and in general for loads less than the maximum the resisting moment of the steel based on average deformation for the full gauge length is considerably less than the bending moment. It seems probable that at the vertical cracks the steel is stretched enough more than the average deformation to give a stress which would make up the full amount of the bending moment. It is also found that for a load of 10,000 pounds the total stress in the steel is approximately the same in all the beams (about 24,000 pounds), although there is a difference in area of the steel and a slight difference in position of the neutral axis found for these beams. There is a similar uniformity at 15,000 pounds and at 20,000 pounds load for beams carrying such loads, the total stresses in the steel being about 42,000 and 64,000 pounds respectively.

Conservation of Plane Section—Some doubt has been expressed concerning the correctness of the time-honored hypothesis that a plane section before bending remains a plane section after bending, and the high results of tests of a special form of reinforcement made by loading with bars and brick have been cited in proof of the fallacy of this principle. To check its correctness, two extensometer devices were used on one side of the beam, the gauge length being made the same in both cases by alternating the frames. One device had its contact points placed 11 inches apart vertically as usual, 1¼ inches below the top of the beam and 1¼ inches above the bottom. In the other the upper points were applied at the usual position, 1¼ inches below the top of the beam, and the lower points were applied 8½ inches below the upper points. In another beam the vertical distance between contact points of the second set was made 6 inches. Readings with the two pairs of extensometers were taken simultaneously as the loading of the beam progressed. From these observations two sets of values of the elongation of the steel and compression of the concrete were determined and also the resulting positions of the neutral surface. The results agree closely, perhaps as closely as the variations in the transmission of the interior deformation to the contact point could be expected to give. It should be noted that this agreement does not hold for loads under 3,000 pounds. In general, however, the neutral axis as determined by one pair of extensometers is a uniform distance below that determined by the other pair, the average variation above the elbow of the curve being .27 inches for Beam No. 22 and .12 inches for Beam No. 27. It should be noted that the measurements were made with an arrangement of loading for which the vertical shear is nearly zero between gauge points and hence that there was little to cause distortion of section.

Position of Neutral Axis—The successive positions of the neutral axis as determined for the various beams are shown on the diagrams. In general, the neutral axis may be said to rise during the second or readjustment stage and then to remain in one position during the third stage until the maximum load is reached. For part of the beams the position of the neutral axis beyond the maximum load is shown, this position being higher than at the maximum load.

For beams which developed the full compression strength of the concrete before the maximum load was reached, the neutral axis finally lowered somewhat. The neutral axis is in general lower than is given by several theories which have been proposed. The positions of the neutral axis during the third stage, in beams with different forms of reinforcement, agree fairly well with each other, as is shown by the diagram (Fig. 7) where the change of neutral axis with the amount of reinforcement is apparent. The line $k = 0.26 + 18p$ gives the position somewhat accurately, where k is the proportional depth of the neutral surface and p is the proportional steel area or ratio of area of steel to area of concrete, the depth from the top of the beam to the center of the steel being used in both cases. Theoretical considerations indicate that the locus of the neutral axis should be a curved line, but its deviation from a straight line within the usual limits of reinforcement will be slight, as is shown in a later discussion.

COMPRESSIVE STRESSES—Little can be said here concerning the compressive stresses in the concrete except to call attention again to the fact that the full compressive strength was not developed even with concrete considered by many to be too lean, except in the case of beams having a large area of metal. It would seem almost that the ordinary formulas give a larger compressive stress at the remotest fiber than actually exists there. The relation between stress and deformation near the crushing strength of concrete is probably different from that assumed in such formulas.

SHEAR AND ADHESION—It had been anticipated that some of these beams, particularly those having a large area of reinforcement, might fail by shearing, or more strictly by diagonal tensile stresses induced by shear. As a means of counteracting this, a portion of the bars in beams with 1 square inch metal or more were bent upward outside the one-third points of the beam and inclined diagonally to points about 4 inches below the top at the ends. The Kahn bars of course were not treated in this way. In no case was there a crack or failure of the kind usually attributed to shear. Whether such failure would have occurred with the bars continued horizontally to the end cannot be told.

There was no indication of slipping of the rods in the concrete even with plain rods. A series of tests made to determine the adhesive bond between plain rods and concrete gave for the size of rods used an average of 300 pounds per square inch of surface of steel. For beams of the dimensions and methods of loading here used, this would indicate for the two sizes of steel used a factor of safety against slipping of 2½ to 4 when the steel is stressed to 33,000 pounds per square inch and of 1¾ to 2½ for steel of 55,000 pounds elastic limit when stressed to its elastic limit. For these beams, then, there is a considerable margin against slipping.

Plain Concrete—Diagrams of Beams No. 11 and No. 18 give the load-deformation diagrams for plain concrete beams. The deformations are given for top and bottom fibers, the beams being 15 feet 4 inches long, 12 inches wide and 13½ inches deep and loaded as were the reinforced beams. It will be seen that the neutral axis is very close to the middle of the depth of the beam. This would indicate that for the beams the coefficient of elasticity of concrete for tension and that for compression are approximately equal.

Other Tests—Among tests made in connection with those described were a series of tests on plain concrete beams, tension, compression, and shearing tests of concrete cylinders to determine relation between deformation and stress, and tension tests of reinforced concrete. Tests were also made on reinforced concrete beams by taking off the load at three or more loads, and noting the deformations as the load was being removed and again put on.

Summary—Extensometer tests were not obtained on three of the beams tested, but the deflections and maximum loads of these three beams checked those of their mates very closely. It is not well to draw general conclusions from one set of tests, but as has been said the behavior and uniformity of test pieces leads the writer to place more reliance than usual in the results of the individual tests, and it seems proper that some deductions from this investigation be pointed out. These may be stated as follows: 1. The composite structure acts as a true combination of steel and concrete in flexure during the first or preliminary stage, and this stage lasts until the steel is stressed to say 3,000 to 4,000 pounds per square inch, and the lower surface of the concrete is elongated $\frac{1}{10000}$ to $\frac{1}{7500}$ of its length. 2. During the second or readjustment stage there is a marked change in distribution of stresses, the neutral axis rises, the concrete loses part of its tensional value, and tensile stresses formerly taken by the concrete are transferred to the steel. During this stage minute cracks probably exist, quite well distributed and not easily detected. 3. In the third or straight-line stage the neutral axis remains nearly stationary in position and the concrete gradually loses more of its tensional value. Visible cracks appear and gradually grow larger, though no change in the character of the load-deformation diagram results. It would seem probable that at these cracks the stress in the steel is more than is indicated by the average deformation for the full gauge length. 4. In beams with the metal reinforcement small enough in amount not to develop the full compressive strength of the concrete, the maximum load is reached or nearly reached when the metal is stretched to its yield point, and in calculating the resisting moment the tensional value of the concrete is here negligible except with light reinforcement, and the load at the yield point of the metal may well be considered the full strength of the beam. 5. So far as strength of the beam is concerned, the load when the steel is stressed to its elastic limit seems the proper basis for the factor of safety and working load. 6. So far as strength of beam is concerned, steel having a high elastic limit is advantageous, it being assumed that there is sufficient provision against the slipping of rods and shearing failures. 7. The determination of the limit of reinforcement which may properly be used with different mixtures and grades of concrete may best be decided by experiments on beams made to determine this. For the 1-3-6 concrete used, reinforcement as high as 1½ per cent for steel of 33,000 pounds per square inch elastic limit and 1 per cent for steel of 55,000 pounds per square inch elestic limit may be used without developing the full compression strength of the concrete. 8. With those beams having sufficient metal to develop the full compression strength of the concrete, the calculated resisting moment of the steel and concrete is in excess of the applied bending moment, which indicates perhaps the center of gravity of the compression stresses is much lower than when the compression stress is well below this limit. 9. There was no marked difference in results found for the different forms of reinforcing bars used. It is assumed here that the beams are subject to simple flexure and that provision is made against shearing stresses and slipping of bars.

The University of Illinois purposes issuing a bulletin giving the results of these tests in detail, and plans are being made for extending the investigation. It should be said that the work of making these tests was done principally as thesis work and that Messrs. R. V. Engstrom, F. E. Mills, S. D. Brown, and R. J. Blackburn of the class of 1904 are entitled to credit for the care, thoroughness, and untiring interest given to the investigation and are to be commended for their skill and thoughtfulness.

RESISTANCE TO FLEXURE.

In this analysis reference is made to reinforced concrete beams subject to simple flexure. It is assumed that the beam will not fail by shear or by secondary tensile stresses and that the work done by the shearing stresses is so slight in comparison with the work of the horizontal stresses as to be negligible in the calculation of resisting moment. Shearing and secondary stresses will require a separate and more complicated analysis. Simple flexure implies that the loads are applied at right angles to the length of the beam, and that the arrangement of the end supports will not permit arch action. The usual assumptions that a plane section before bending remains a plane section after bending and that the metal and surrounding concrete stretch together are made. It is further assumed that the tension strength of the concrete at the time of maximum load is negligible, as shown in the investigation just described.

The following notation will be used:

b=breadth of rectangular beam.

d=distance from the compression face to the center of the metal reinforement.

A=area of cross section of metal reinforcement.

$p=\frac{A}{b\,d}$ = ratio of area of metal reinforcement to area of concrete above center of reinforcement.

E_s=modulus of elasticity of steel.

E_c=initial modulus of elasticity of concrete in compression, a term which will be defined.

$n=\frac{E_s}{E_c}$ = ratio of two moduli.

f=tensile stress per unit of area in metal reinforcement.

c=compressive stress per unit of area in most remote fiber of the concrete.

c'=compressive stress per unit of area which causes failure by crushing.

λ_s=deformation per unit of length in the metal reinforcement.

λ_c=deformation per unit of length in most remote fiber of the concrete.

λ'_c=deformation per unit of length when crushing failure occurs; i. e., ultimate or crushing deformation.

$q=\frac{\lambda_c}{\lambda'_c}$=ratio of deformation existing in most remotest fiber to ultimate or crushing deformation.

k=ratio of distance between compression face and neutral axis to distance d.

z=distance from compression face to center of gravity of compressive stresses

ΣX=summation of horizontal compressive stresses.

M=resisting moment at the given section.

RELATION BETWEEN STRESS AND DEFORMATION FOR CONCRETE IN COMPRESSION.—We must acknowledge at the outset that concrete is variable in its makeup. Even the same mixtures give different deformations for the same compressive forces. Variations in cement and stone, in the mixing, in the rate of setting, in the amount of water, all go to cause this. Further than this, concrete does not possess the property of proportionality of stress and deformation as does steel; in other words, the deformation produced by a load is not proportional to the compressive stress. The relation between stress and deformation is commonly stated to be a parabola.

Fig. 1 shows the stress-deformation curve for a 1-3-6 concrete cylinder 90 days old of the materials used in the beams described in this paper which was tested by Mr. R. H. Slocum, Instructor in Theoretical and Applied Mechanics in the University of Illinois. The test piece was 8 inches in diameter and 20 inches long. The deformations were measured with a gauge length of 12 inches by extensometers reading to $\frac{1}{10000}$ inch. The abscissas represent compressive stresses or loads in pounds per square inch.

The ordinates represent deformations per unit of length or, what is the same thing, shortenings in inches per inch of length. The piece failed at 1800 lb. per square inch. Possibly flexure of the specimen due to slight eccentricity of loading acted to induce failure somewhat under the real compressive strength of the concrete. The diagram is an almost perfect parabola having its vertex at the point of failure, 1800 lb. per square inch, and its axis on the top line of the figure. It is rare to find a stress-deformation diagram which a parabola will fit so well or which any curve will fit so well. In many cases an exponential curve will best fit the observed points, and in some respects such a form of curve is more convenient, but as the parabola is frequently used for this purpose it will be adopted here.

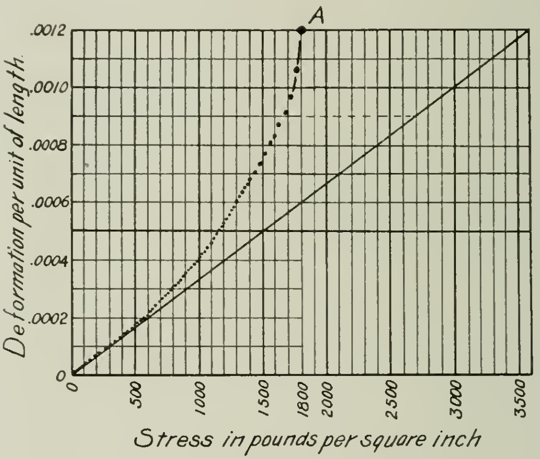


Fig. 1 Stress-deformation Diagram for Concrete Cylinder in Compression.

Using x and y as coordinates and a and b as constants and placing the origin at the zero of stress and deformation, the equation of this parabola is of the form $x = ay - aby^2$, or if we use λ_c for y, c for x, and E_c (which will be defined later) for a, the general equation becomes

$$c = E_c\lambda_c - bE_c\lambda_c^2 \ldots\ldots(1)$$

where b is one-half of the reciprocal of the deformation at failure, that is at the full compressive strength of the concrete, provided this law for stress-deformation is followed to the vertex of the parabola.

The term coefficient or modulus of elasticity is used with materials having a proportionality of deformation to stress to express this relation; the deformation per unit of length multiplied by the modulus of elasticity will give the stress per unit of area. Concrete does not possess this proportionality; the factor for multiplying the deformation produced to obtain the stress producing it is variable. Hence the use of modulus of elasticity in connection with formulas for flexure of concrete may lead to misunderstandings. However, it is convenient to have a term to express the relation between stress and deformation. Using x and y as coordinates, the equation of the tangent to the parabola at zero load shown in Fig. 1 is

$$x = E_c y \ldots\ldots (2)$$

This tangent line represents the relation which would exist between stress and deformation if the concrete compressed uniformly at the rate it started out to compress, and E will be called the initial modulus of elasticity of the concrete. The term $E_c\lambda_c$ of equation (1), then, gives the stress which would compress an amount λ_c if proportionality held, but the last term of the equation reduces the stress by an amount which varies with the square of the deformation.

Continuing the study of Fig. 1, it may be seen that a slightly smaller stress than the crushing value has a considerably smaller deformation; thus 1687 lb. per sq. in. gives a deformation of .0009; or $\frac{15}{16}c'$ gives $\frac{3}{4}\lambda'_c$, using c' and λ'_c as the ultimate values of c and λ_c, and $\frac{3}{4}c'$ produces a deformation of $\frac{1}{2}\lambda'_c$. Conversely a considerable reduction in the amount of the deformation will result in but a slight decrease in stress. For small stresses the stress-deformation curve does not differ much from the line of initial modulus of elasticity.

Distribution of Stresses in Beam—Let Fig. 2 show the section of the beam. kd is the distance of the neutral axis below the top of the beam, k being a ratio. In Fig. 3, the left diagram represents the deformations above and below the neutral axis. Consider that the upper fibre is stressed to the point of failure; the upper deformation will then be the ultimate or crushing deformation. Since the deformations are proportional to the distances from the neutral axis, the curve of compressive stresses shown on the right will be a parabola with its vertex at o. The horizontal

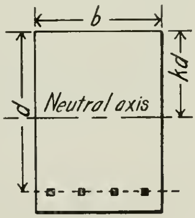


Fig. 2. Section of Beam.

distances to the "line for initial modulus of elasticity" represent the stresses which would exist for the same deformation with a constant modulus of elasticity equal to E_c. The stress in the steel is represented by a length proportional to the ratio of the modulus of elasticty of the steel to the initial modulus of elasticity of the concrete $\left(n=\frac{E_s}{E_c}\right)$. In like manner Fig. 4 gives the stress and deformation distribution for a deformation of the upper fiber equal to three-fourths of the ultimate deformation of the concrete and a stress of fifteen-sixteenths of the crushing stress. Fig. 5 shows a similar distribution for one-half ultimate deformation and three-

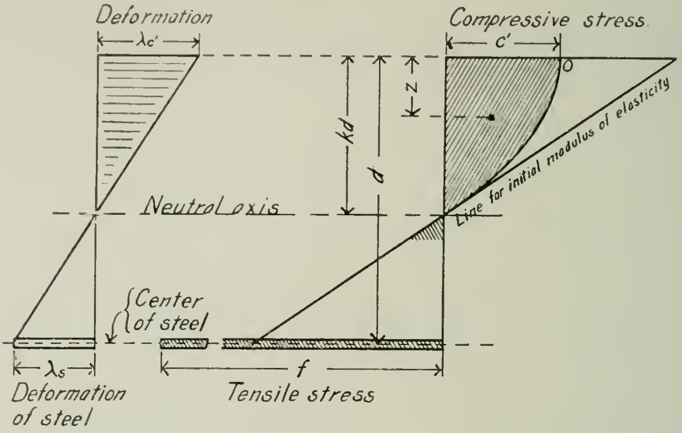


Fig. 3. Stress and Deformation Distribution at Ultimate Deformation.

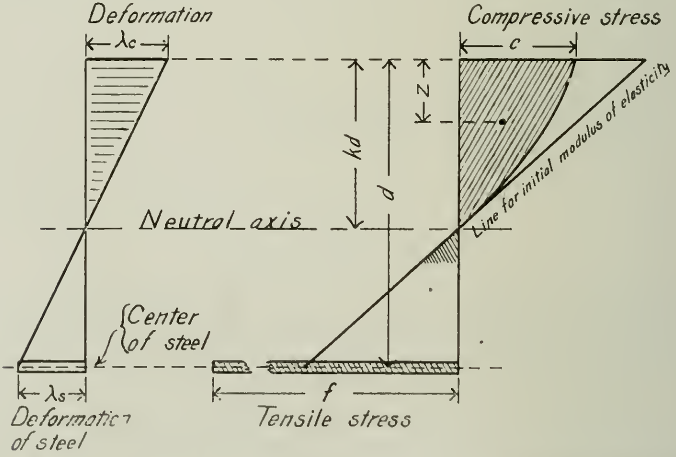


Fig. 4. Stress and Deformation Distribution at Three-fourths Ultimate Deformation.

fourths crushing stress. It will be noted that the parabolic arc appears somewhat different from that in Fig 3, and that it differs much less from the line for initial modulus of rupture.

RELATIONS IN THE STRESS DIAGRAM—In deriving formulas for resisting moment, position of neutral axis, and compressive stress at upper fiber, three relations in the stress diagram are needed: (1) the relation of the stress c and the deformation λ_c at the upper fiber; (2) the total compressive stress, here called ΣX; and (3) the position of the center of gravity of the compressive stresses given by the distance z. These relations vary for different values of the deformation in upper fiber. Basing the variation on the parabolic stress deformation law previously stated, and using $q=\frac{\lambda_c}{\lambda_c'}$ as the ratio of the deformation developed in the upper fiber to the ultimate deformation of the concrete, the following relations are readily deduced, though their derivation will not be given here.

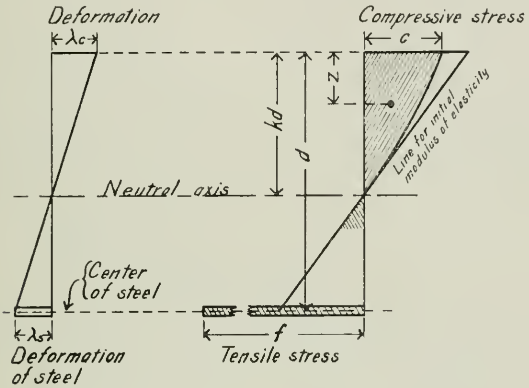


Fig. 5. Stress and Deformation Distribution at One-half Ultimate Deformation.

$$\frac{c}{E_c\lambda_c}=1-\frac{1}{2}q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$\frac{\Sigma X}{\frac{1}{2}E_c\lambda_c kbd}=\frac{\text{Parabolic area}}{\text{Triangular area}}=1-\tfrac{1}{3}q \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$\frac{z}{kd}=\frac{4-q}{12-4q}=\tfrac{1}{3}\left(1+\tfrac{1}{4}\,\frac{q}{3-q}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Equation (3) gives the ratio of the compressive stress in the upper fiber to the stress which would exist for the same upper deformation with a straight-line stress-deformation relation. Equation (4) gives the ratio of the summation of compressive stresses to the stress which would exist for the same upper deformation with a straight-line stress-deformation relation. Equation (5) gives the ratio of the distance between the compression surface and the center of gravity of compressive stresses to the distance between that surface and the neutral axis.

Values for several ratios of upper to ultimate deformation are given in the following table :

TABLE.

Properties of the Stress Diagram.

Property.	At ultimate deformation.	At $\frac{3}{4}$ ultimate deformation.	At $\frac{1}{2}$ ultimate deformation.	At $\frac{1}{4}$ ultimate deformation.
c	$\frac{1}{2}E_c\lambda_c$	$\frac{5}{8}E_c\lambda_c$	$\frac{3}{4}E_c\lambda_c$	$\frac{7}{8}E_c\lambda_c$
ΣX	$\frac{1}{3}E_c\lambda_c kbd$	$\frac{3}{8}E_c\lambda_c kbd$	$\frac{5}{12}E_c\lambda_c kbd$	$\frac{11}{24}E_c\lambda_c kbd$
z	$\frac{3}{8}kd$	$\frac{13}{36}kd$	$\frac{7}{20}kd$	$\frac{15}{44}kd$

Fig. 6 shows graphically the relations given by equations (3), (4) and (5). It will be seen that the center of gravity of the compressive stresses ranges from $\frac{3}{8}$ distance down to neutral axis (the value for a deformation equal to the ultimate deformation) to $\frac{1}{3}$ distance down to neutral axis at the lower limit. The position for $q=\frac{3}{4}$ is $\frac{13}{36}$ equal to .36. This is not far from the value $\frac{4}{11}$ which was used in the discussion of the experimental work, and which was obtained by another method of analysis. The other ratios are less near constant. The ratio for compressive stress at most remote fiber to that for direct proportionality with same deformation $\left(\frac{c}{E_c\lambda_c}\right)$ ranges from $\frac{1}{2}$ when

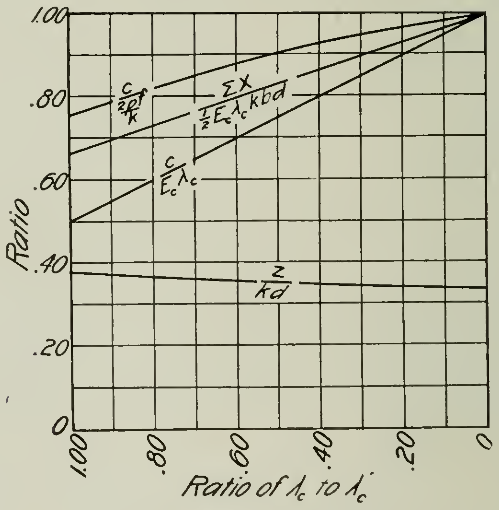


Fig. 6. Variation of Functions with q.

ultimate deformation of concrete is developed to 1.0 for no deformation. The range for summation of compressive stress is from $\frac{2}{3}$ to 1.0. It should be remembered that these formulas are not applicable when tensile stresses of concrete need consideration.

Neutral Axis—The foregoing relations and the analytical condition that the total horizontal compressive stresses and the total horizontal tensile stress are equal will, if tensile stresses in the concrete be neglected, readily enable the position of the neutral axis to be determined for rectangular beams. From the proportionality of deformation (Fig. 3, 4 and 5),

$$\frac{\lambda_s}{1-k}=\frac{\lambda_c}{k} \quad \ldots\ldots\ldots\ldots \quad (6)$$

Equating horizontal stresses,

$$Af=\tfrac{1}{2}(1-\tfrac{1}{3}q)E_c\lambda_c kbd \quad \ldots\ldots\ldots\ldots \quad (7)$$

Dividing 7 by 6 and substituting $f=E_s\,\lambda_s$,

$$AE_s(1-k)=\tfrac{1}{2}(1-\tfrac{1}{8}q)E_c k^2 bd$$

Calling $\frac{E_s}{E_c}=n$ and $\frac{A}{bd}=p$,

$$pn(1-k)=\tfrac{1}{2}(1-\tfrac{1}{3}q)k^2$$

Solving

$$k=\sqrt{\frac{2\,pn}{1-\frac{1}{3}q}+\frac{p^2n^2}{(1-\frac{1}{3}q)^2}}-\frac{pn}{1-\frac{1}{3}q} \quad \ldots\ldots \quad (8)$$

This gives the position of the neutral axis after tensile stresses in the concrete have become negligible and before the concrete reaches its ultimate strength. The value of k will vary slightly for the range of q usually considered, probably not more than .02. Selecting ¾ as a mean value for q we may consider that the resulting equation is applicable on either side within allowable limits of error. This value of k becomes

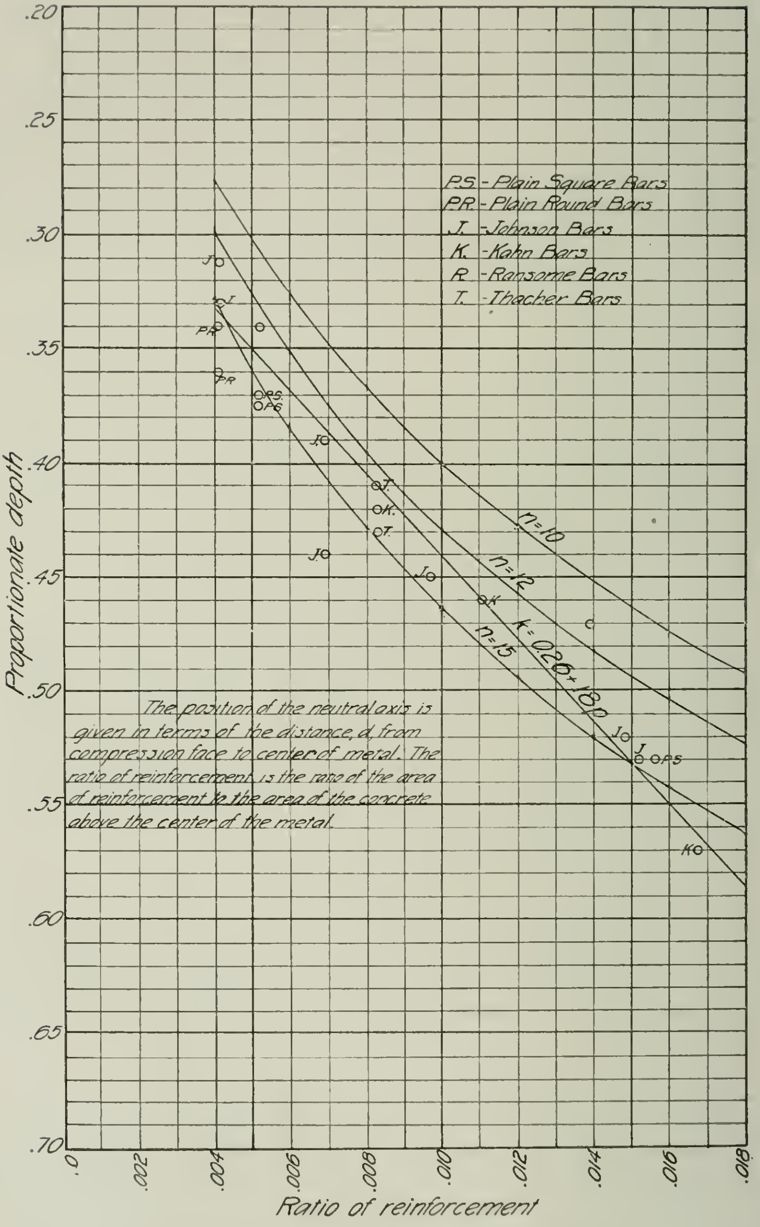
$$k=\sqrt{\frac{8}{3}pn\,(1+\tfrac{2}{3}\,pn)}-\frac{4}{3}\,pn \quad \ldots\ldots\ldots\ldots \quad (9)$$

Equation (9) may be used without great error for values of q other than $\frac{3}{4}$. The diagram (Fig. 7) gives values of k from equation (9) for $n=10$, 12, and 15. It may be seen that within the usual limits of reinforcement these curves are closely approximated by straight lines, and that for

$n=10$, $k=.23+16p$; for $n=12$, $k=.25+16p$; and for $n=15$, $k=.28+17p$

express the position of the neutral axis very closely.

Resisting Moment—When the tensile stresses in the concrete are neglected and the center of gravity of the compressive stresses is known the value of the resisting moment of the beam (which it is readily seen is the moment of the couple formed by the tensile stress in the steel and the resultant of the compressive stresses in the concrete) is easily expressed as the product of the tensile



The position of the neutral axis is given in terms of the distance, d, from compression face to center of metal. The ratio of reinforcement is the ratio of the area of reinforcement to the area of the concrete above the center of the metal.

Fig. 7. Neutral Axis and Amount of Reinforcement.

Proportionate Depth of Neutral Axis is given in terms of distance from compression face to center of metal.

stress in the steel and the distance from the center of the steel to the center of the gravity of the compressive stresses. Hence the formula for the resisting moment for a rectangular beam is

$$M=Af\,(d-z). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

It was shown that z varies slightly for different compressive stresses. Using the value of z for conditions when the concrete is stressed to three-fourths of its ultimate deformation, this becomes for a rectangular beam

$$M=Af\,(1-.36k)\,d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

For conditions when the concrete is stressed to one half its ultimate deformation the formula is

$$M=Af\,(1-.35k)\,d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

As the analytical expression for the position of the neutral axis is complicated, and as the curve representing this does not vary far from a straight line within the usual limits of reinforcement, a simple formula for k may be derived by substituting a straight line relation taken from the theoretical curve or from the results of tests. Using the experimental value of k given in the foregoing description for the 1-3-6 beams tested, the formula becomes

$$M=Af\,(.906-6\tfrac{1}{2}p)\,d \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

This reduces to M=.84 Afd for 1 per cent reinforcement and .81 Afd for 1.5 per cent reinforcement. The straight line relations given in the discussion of the position of the neutral axis will give similar formulas. This form of formula is convenient for use in calculating strength of beams.

COMPRESSIVE STRESS AT UPPER FIBER.—The formulas for the position of the neutral axis and moment of resistance are based upon the assumption that the compressive stress in the upper fiber is within the crushing strength. To determine the value of the upper compressive stress substitute equation (3) in equation (7).

This reduces to

$$c=\frac{2Af}{kbd}\cdot\frac{1-\frac{1}{2}q}{1-\frac{1}{3}q}=\frac{2pf}{k}\cdot\frac{1-\frac{1}{2}q}{1-\frac{1}{3}q} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

For a deformation of upper fiber equal to three-fourths of deformation at crushing $\left(\text{or } c=\frac{15}{16}c'\right)$, this becomes $c=\frac{5}{6}\frac{2pf}{k}$. For an upper deformation equal to one-half of ultimate deformation this becomes $c=\frac{9}{10}\frac{2pf}{k}$. For the crushing point of the concrete it becomes $c=\frac{3}{4}\frac{2pf}{k}$. As the upper deformation decreases, the value of c approaches $\frac{2pf}{k}$, which is the amount of the stress for a constant modulus of elasticity equal to the initial modulus of elasticity. By multiplying $\frac{2pf}{k}$, the stress found on the basis of a constant modulus of elasticity and a known position of the neutral axis, by this ratio $\frac{1-\frac{1}{2}q}{1-\frac{1}{3}q}$ the value of the compression stress is found. The variation in this ratio may be seen in the upper line in Fig. 6.

Value of Initial Modulus of Elasticity—The determination of the value of the initial modulus of elasticity is a matter for experimental investigation. In getting the initial modulus of elasticity from stress-deformation diagrams, points early in the curve rather than at the crushing point should control, since the action at and near the crushing point may be quite variable. The exact basis for such a determination will need study and discussion. It is to be expected that different mixtures of concrete, different degrees of porosity, and different degrees of dryness of the concrete will give different values. Preliminary calculations for the 1-3-6 concrete used in reinforced concrete beams, plain concrete beams, and compressive test pieces of the investigation herein described give values ranging from 1,800,000 to 2,500,000, with a mean of 2,000,000. This makes the ratio n from 12 to 17.

Other Forms of Section—The analysis may be modified to apply to tee-shapes and other forms of section. For the tee-shape when the top width extends down to the neutral axis the full top width may be used for b in the formulas just given. For other conditions further modifications will be necessary to determine the position of the neutral axis and the center of gravity of compressive stresses.

Discussion—This analysis is presented with the hope of aiding in putting calculations on a better analytical basis. If the parabolic stress-deformation relation is correct, as is usually assumed, the analytical theory is tenable. The method outlined involves the use of the ratio q for which a value must be selected tentatively, but the resisting moment and the position of the neutral axis and the center of gravity of the compressive stresses are not much affected by variations in q within the usual range. It is recognized that the constants E_c and λ_c must be determined for a variety of concretes and that the applicability of the theory must be subjected to verification by wider experimental investigation. Experiments will be needed before deciding whether the initial modulus of elasticity should be determined for continuous loading or for released loading. In passing, attention should be called to the fact that in the derivation of formulas in the literature of reinforced concrete the parabolic stress-deformation relation is sometimes loosely and even inconsistently used. For example, to call the compressive stress distribution in a beam a parabola and then call the modulus of elasticity a constant is illogical.

The writer appreciates that very much is yet to be discovered concerning the internal condition of concrete while subjected to stress. For illustration take the case of the release of the loads on a beam. Careful observations show that during and after the release of the load the fibers of the beam must be under stress, and that this condition is different from what is ordinarily termed set. This is an important subject for further investigation. It may be important to know whether the crushing strength or the ultimate deformation of the concrete is the more variable or is more largely influenced by poor mixtures and poor workmanship and hence to know which is more important as a basis for a factor of safety. The diagrams for the beams show little change in character of the compression curve up to a deformation of .0012 or even .0016. It is possible that the allowable amount of compressive deformation will lower the limit set for useful yield point of metal below what is indicated in the discussion of the experiments. The effect of encasing steel in concrete upon the elastic properties of steel, i. e., whether the modulus of elasticity of steel encased in concrete is the same as that for naked steel, and the amount and effect of shrinkage and other initial stresses need study. It is hoped that the investigation now being planned by the Joint Committee on Reinforced Concrete of the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association, and the Association of American Portland Cement Manufacturers will include points brought up in this paper and that it will be productive of important results in many directions. If the experiments and analyses here given serve to help clear up some points and to open up the field for further investigation the purpose of its writing will be accomplished.

NOTE.—The following seven pages of diagrams illustrates graphically the results of some of the tests of concrete beams described by Prof. Talbot.

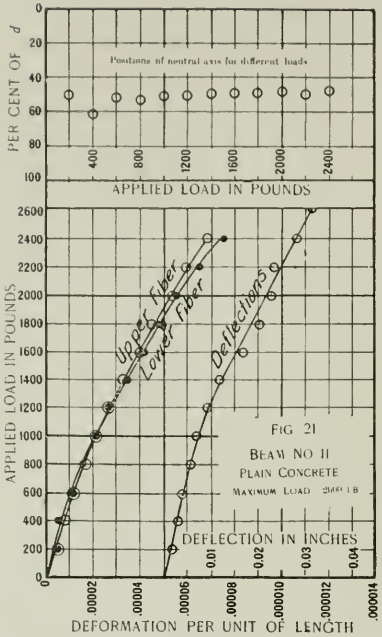


FIG 21
BEAM NO 11
PLAIN CONCRETE
MAXIMUM LOAD 2600 LB

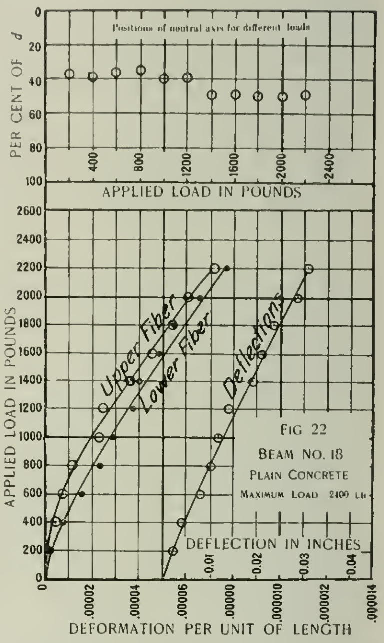


FIG 22
BEAM NO. 18
PLAIN CONCRETE
MAXIMUM LOAD 2400 LB

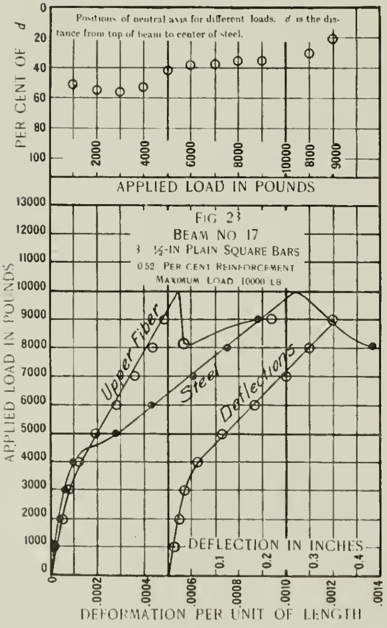


FIG 23
BEAM NO 17
3 ½-IN PLAIN SQUARE BARS
0.52 PER CENT REINFORCEMENT
MAXIMUM LOAD 10000 LB

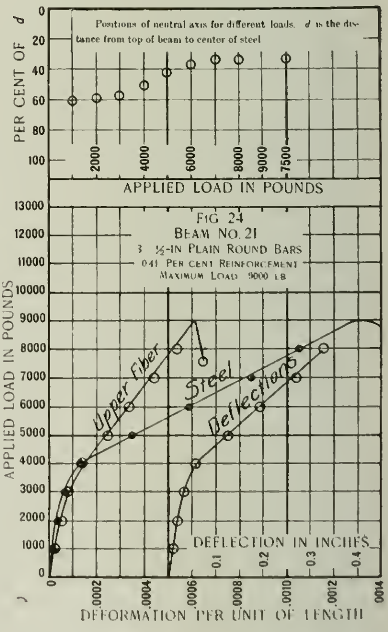
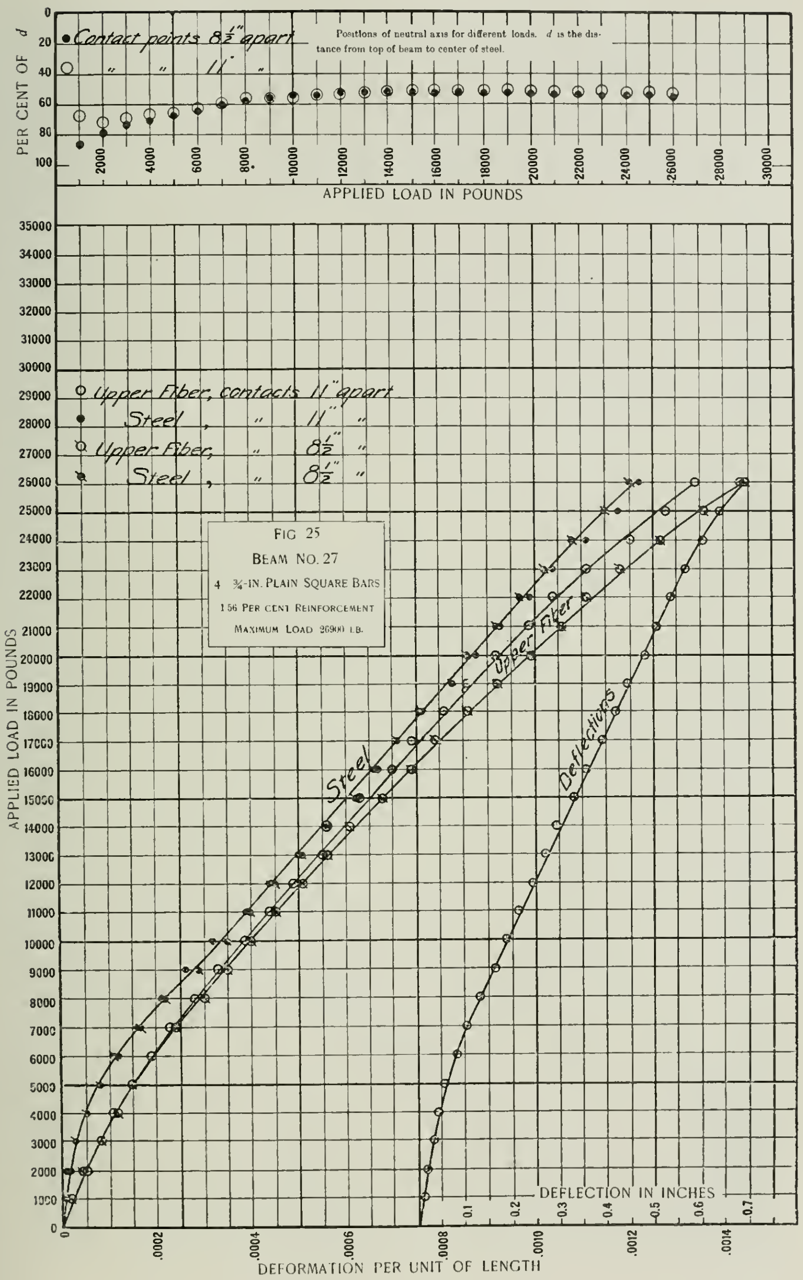


FIG 24
BEAM NO. 21
3 ½-IN PLAIN ROUND BARS
0.41 PER CENT REINFORCEMENT
MAXIMUM LOAD 9000 LB



Positions of neutral axis for different loads. *d* is the distance from top of beam to center of steel.

FIG 25

BEAM NO. 27

4 ¾-IN. PLAIN SQUARE BARS

1.56 PER CENT REINFORCEMENT

MAXIMUM LOAD 26900 LB.

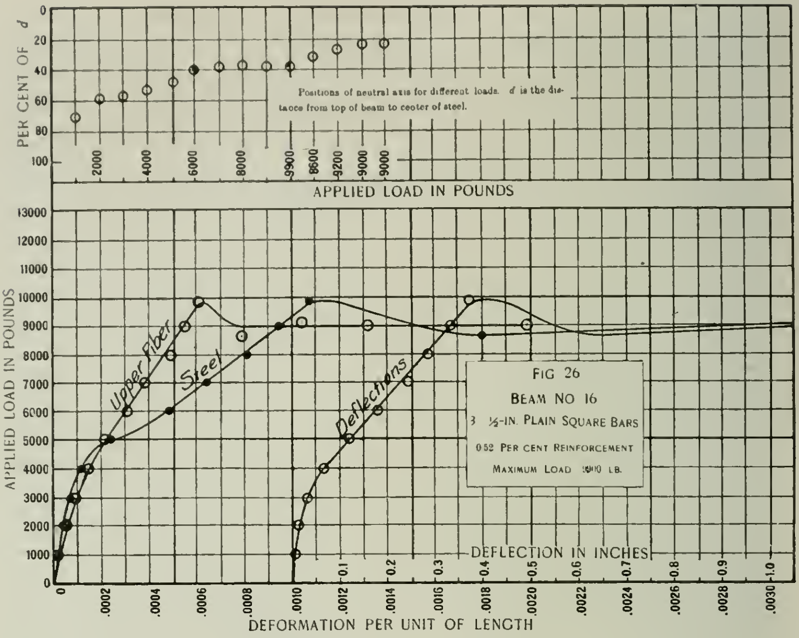


FIG 26

BEAM NO 16

3 ½-IN. PLAIN SQUARE BARS

0.52 PER CENT REINFORCEMENT

MAXIMUM LOAD 9900 LB.

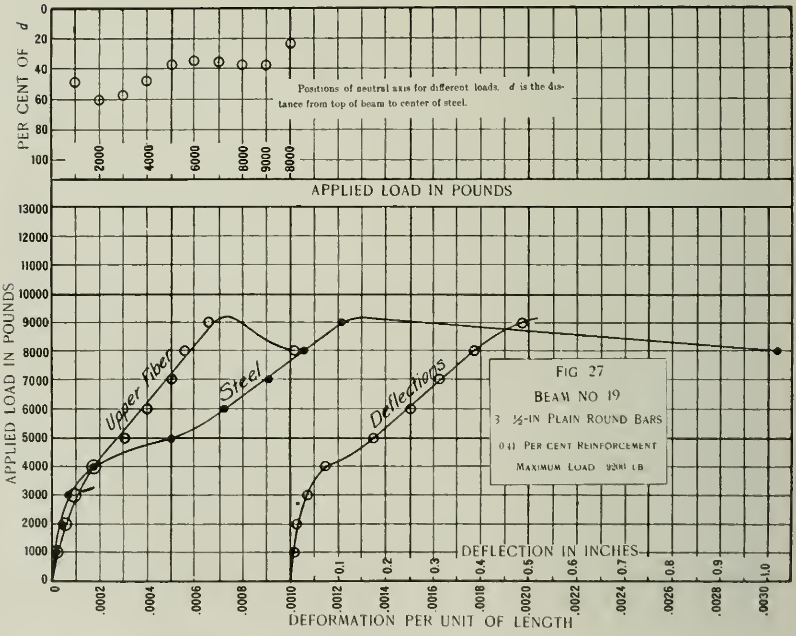


FIG 27

BEAM NO 19

3 ½-IN PLAIN ROUND BARS

0.41 PER CENT REINFORCEMENT

MAXIMUM LOAD 9200 LB

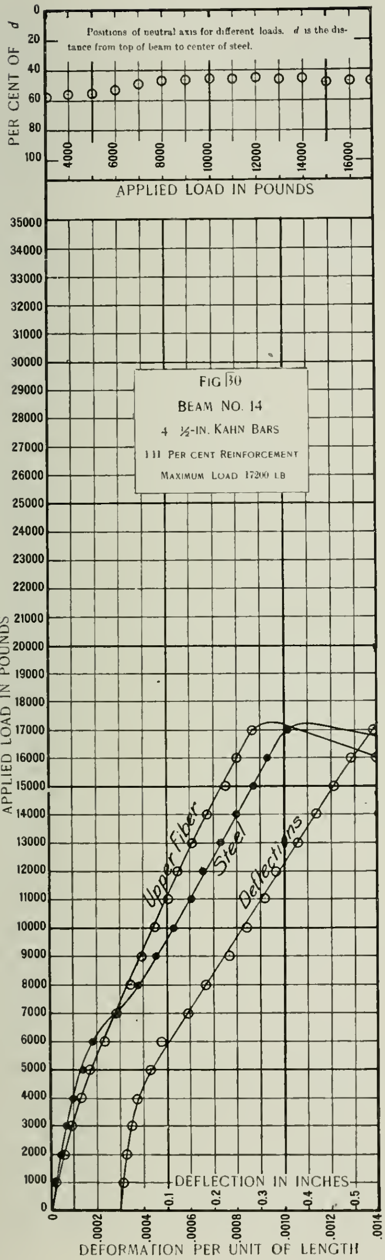


FIG 30

BEAM NO. 14

4 ½-IN. KAHN BARS

1.11 PER CENT REINFORCEMENT

MAXIMUM LOAD 17200 LB

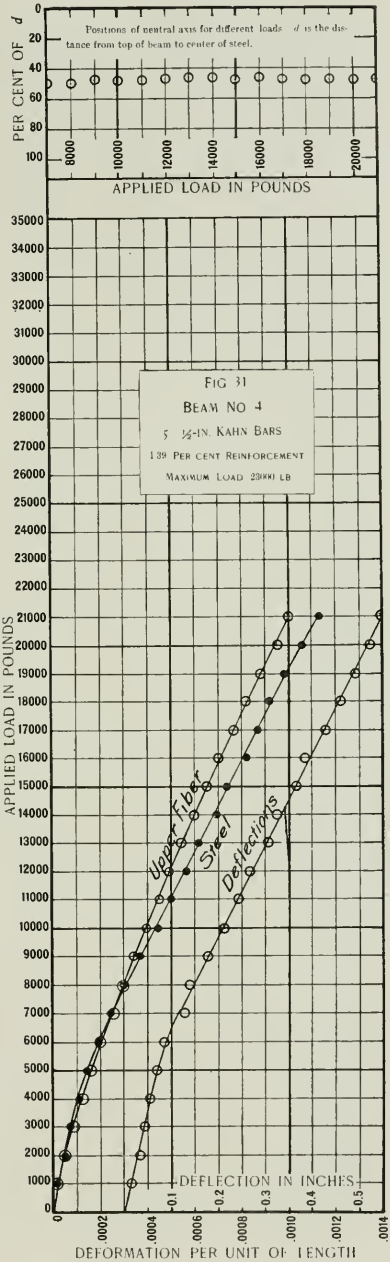


FIG 31

BEAM NO 4

5 ½-IN. KAHN BARS

1.39 PER CENT REINFORCEMENT

MAXIMUM LOAD 23000 LB

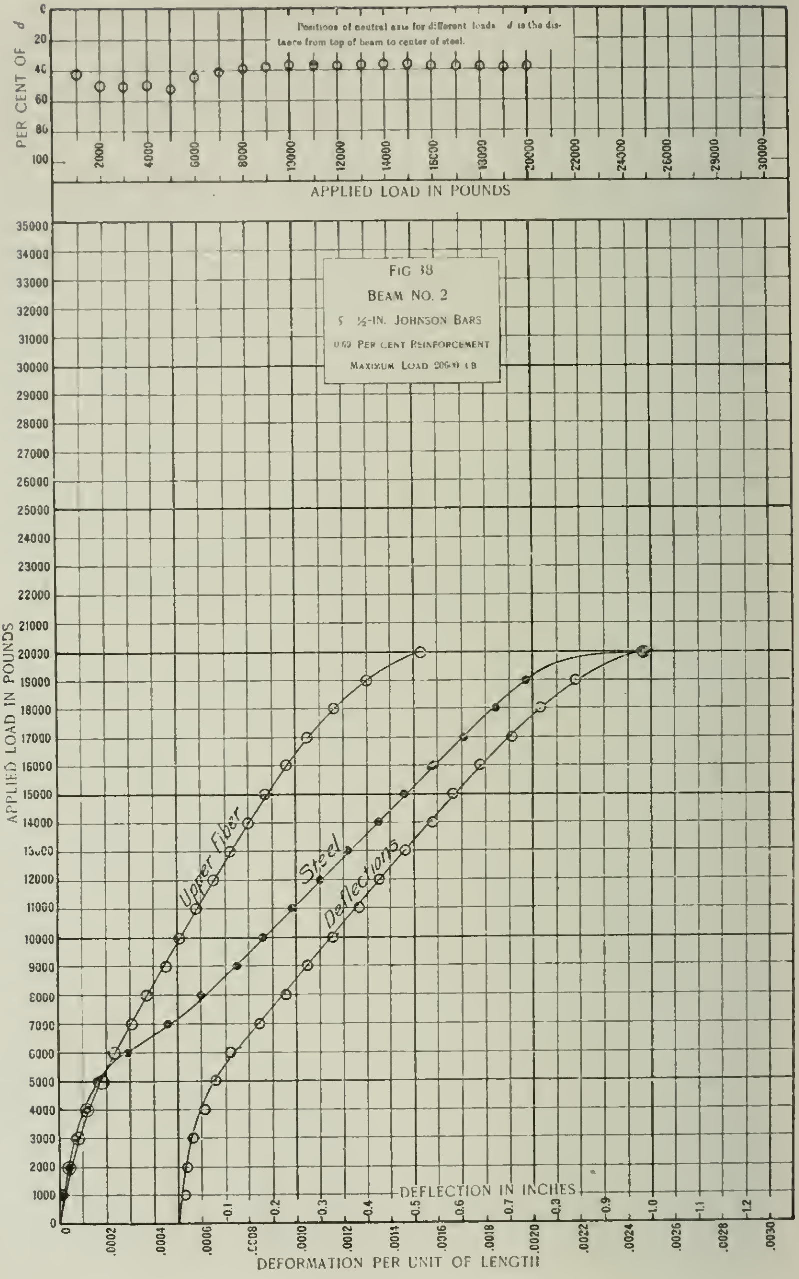


FIG 38

BEAM NO. 2

5 ½-IN. JOHNSON BARS

0.69 PER CENT REINFORCEMENT

MAXIMUM LOAD 20600 LB

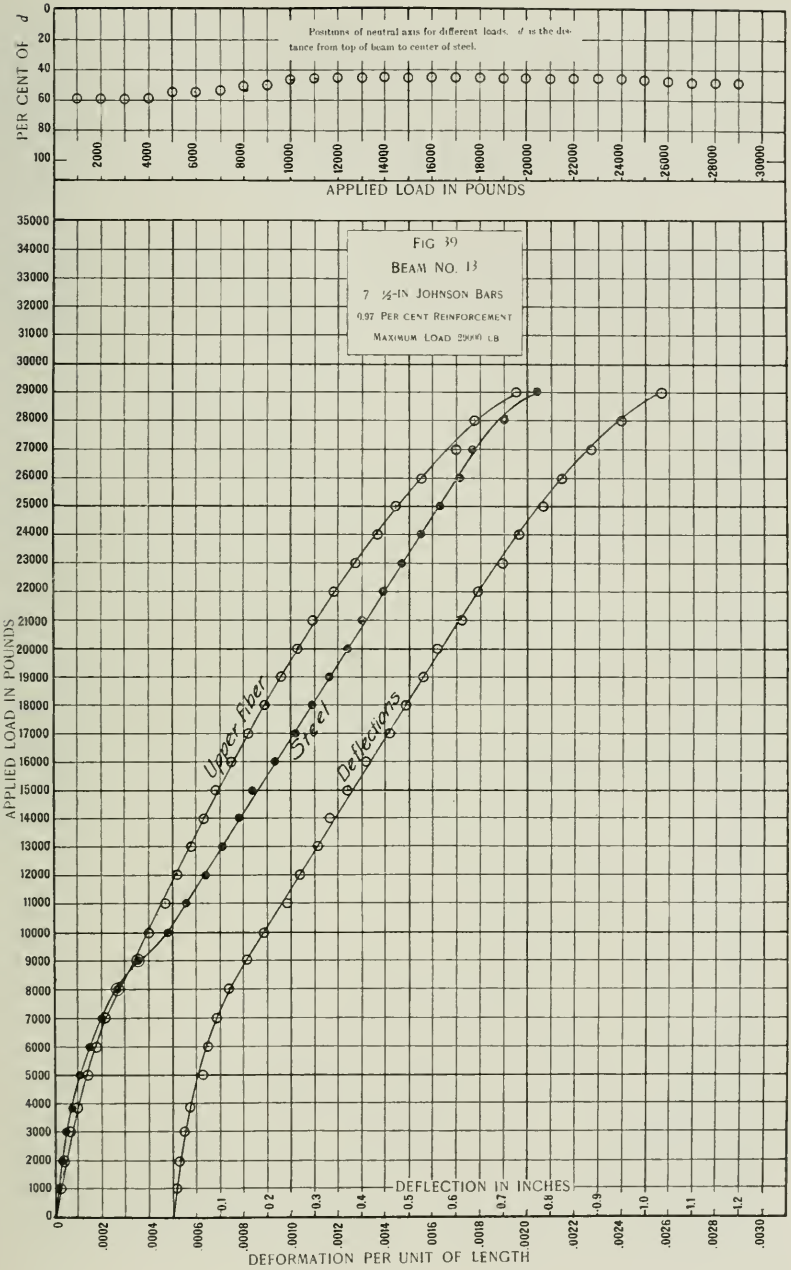


Fig 39

Beam No. 13

7 ½-in Johnson Bars

0.97 Per cent Reinforcement

Maximum Load 29000 lb

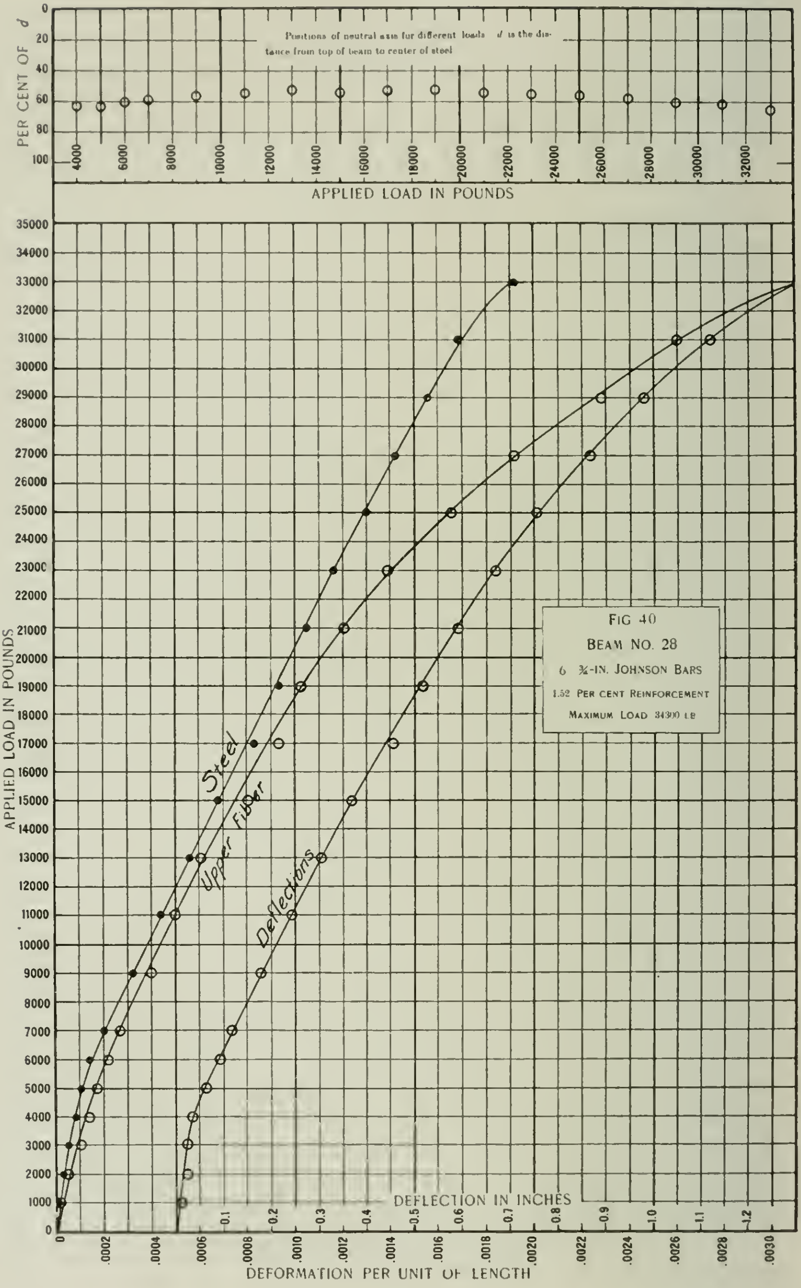


FIG 40

BEAM NO. 28

6 ¾-IN. JOHNSON BARS

1.52 PER CENT REINFORCEMENT

MAXIMUM LOAD 34300 LB

THE ELECTRICAL SECTION, W. S. E.

SOME OF THE ELECTRICAL FEATURES OF THE EXPOSITION.

E. B. Ellicott, M. W. S. E., Chief Mechanical and Electrical Engineer of the Louisiana Purchase Exposition, St. Louis, 1904.

Read June 24, 1904.

A mere outline of the scope of the electrical work and equipment at the Louisiana Purchase Exposition at St. Louis would make a lengthy paper of itself, and to enter into details would fill a book. Consequently I can only touch upon such points as I think may be of general interest and enable you to form some idea of the important part electricity plays in what has been admitted by all to be the greatest of expositions.

The primary intention to have but one power plant within the grounds and to distribute all power by electrical transmission was only deviated from in four minor instances, and it is seldom that such original intentions are so closely followed in the execution of work of such magnitude.

The original estimate for power aggregated 41,000 h. p.—31,000 of which was to be furnished from the exposition plant and 10,000 h. p. was to have been supplied under contract from a local lighting company. A revision of the estimate was made in January and resulted in the cancelling of the contract with the local company, as the actual requirements had been very much overestimated. The power building proper contains the following equipment:

16	400	H. P.	B. & W. boilers.
16	400	"	Cahall boilers.
3	250	"	Cahall boilers.
8	400	"	Heine boilers.
3	400	"	Belleville boilers.
2	400	"	Nicclaussee boilers.
2	250	"	Climax boilers.
1	400	"	Durr boilers.
1	400	"	Conti-Schutte boilers.

The guaranteed evaporating capacity of these boilers aggregates 776,500 pounds of water per hour. It is interesting to know that all but two of the American makes of boilers are equipped with automatic stokers or chain grates, while none of the foreign boilers use other than plain grates, and their representatives seemed not to know anything about our more modern practice in this respect.

The boiler pressure for general use is 175 pounds per square inch, while seven of the boilers are to be operated at 200 pounds pressure per square inch for steam turbine purposes. With the exception of six small boilers, mechanical induced draft is used, each battery of boilers being equipped in duplicate.

There is also located in this building, in addition to the usual boiler feed pumps, heaters, purifiers, etc., four Westinghouse engines direct connected to centrifugal pumps for circulating water used in the condensing system, and 14 duplex steam pumps for the high pressure water system.

The engine room proper is in Machinery Hall, a building located about 200 feet from the power house or boiler room. The engines are so located in Machinery Hall that the largest unit, a 5,000 h. p. engine is nearly 900 feet from the center of the boiler equipment, and the twenty other engines are located at various points along the line. Five steam lines supply these engines, one of 18-inch, one of 16-inch, one of 14-inch and two of 12-inch diameter. To those who have not had actual experience in designing and installing steam lines of such length and diameter it will doubtless appear to be no difficult task, but those who have had such experience will readily appreciate the statement that in the entire plant there was no more difficult problem encountered than that of providing for the expansion in the lines and of making them steam tight. By actual measurement the expansion in the largest line was 16⅝ inches. In the two longest lines but two leaks developed during the first five weeks of service and the two leaks were due to cracks in flanges.

The steam and electrical units consist of the following:

Allis-Chalmers Corliss engine and Bullock 3,500 k. w. generator.

General Electric turbine and 2,000 k. w. generator.

Hamilton-Corliss engine and National 1,500 k. w. generator.

2 Westinghouse Corliss engines and 2 Westinghouse 2,000 k. w. generators.

2 Westinghouse Corliss engines and 2 Generai Electric 2,000 k. w. generators.

Hamilton-Corliss turbine and Bullock 1,000 k. w. generator.

These units aggregate 16,000 k. w. of energy and are designed to generate three-phase 25-cycle alternating current at an initial potential of 6,600 volts. The switch-board arrangement is not ideal, but sufficiently flexible for all practical purposes. The four 2,000 k. w. Westinghouse and General Electric generators are arranged to operate in parallel on either one or both of two sets of bus bars, and every circuit may be thrown on either set of bus bars.

One set of bus bars is provided in the center with an oil switch in order that one-half may be used as bus bars for the 3,500 k. w. Bullock, 2,000 k. w. Turbo and 1,500 k. w. National generators. As each of the circuits entering the switchboard is provided with double throw oil switches, the load may be transferred as desired.

The last named units are connected to and are to operate in parallel from a sub-board located about 300 feet from the main board. The transfer from the sub-board to the main board is made by means of three 300,000 c. m. three-phase cables in parallel which pass through an 8,000 k. w. oil switch. All of the oil switches are electrically controlled and the circuit switches are provided with overload release relays, allowing the switches to be used as circuit breakers.

These 25-cycle units are used to supply the general lighting and power requirements for the exposition. For arc lighting in the outlying sections and partial lighting in the buildings there has been provided the following units, generating 50-cycle alternating current:

Willans engine and 600 k. w. Stanley generator.

Mulhausen engine and 700 k. w. Society Alsaccienne generator.

Buffalo Forge engine and 132 k. w. Stanley generator.

Delaunay-Belleville engine and 1,000 k. w. Belleville generator.

Skinner engine and 150 k. w. Warren generator.

As two of these generators are three-phase, one single-phase and two are two-phase, the switchboard arrangements are somewhat complicated and the system is not very flexible.

For the intramural railroad the following units were installed:

Lane & Bodley Corliss engine and 600 k. w. Crocker-Wheeler generator.

Harrisburg engine and 400 k. w. Crocker-Wheeler generator.

Murray engine and 500 k. w. Crocker-Wheeler generator.

Buckeye engine and 900 k. w. Crocker-Wheeler generator.

Two Brown-Corliss engines and 500 Crocker-Wheeler generator.

These generators are connected to a separate switchboard located on the north side of the building.

There are only two other direct current units in service for power purposes—an American Ball engine and 125 k. w. 125 volt generator and a Greenwald-Corliss engine with a 400 k. w. 250 volt Fort Wayne generator.

For exciter units there are three Westinghouse engines and 125 k. w. Westinghouse generators, one Ideal engine and 200 k. w. Bullock generator, and a small turbo set for the General Electric turbo-generator exhibit.

All of the steam units with the exception of three small engines are of the compound condensing type and in every instance the generator is direct connected to the engine shaft. There is not a belt used in connection with the generation of any of the electric current in the power plant.

Other generators are excited with either direct connected exciter on main engine shaft or by means of motor driven sets.

From the main switchboard 17 three-phase lead covered cables are run in a subway to points where they branch off into conduits to the respective buildings or sections of the grounds that each cable is to supply.

There are three divisions of service required First, commercial lighting of the exhibits in buildings, the Pike and state sections; Second, decorative lighting of the buildings and grounds; Third, motors for cascade pumps and motor generator sets.

As a rule the circuits are all operated from one set of bus bars with the exception of the cascade motor circuits, which, on account of the great size of the motors, proved to be too much of a disturbance on the lines. Special provisions were made to operate these motors from generators temporarily assigned for the purpose.

The motor-generator and rotary-converter sets are placed in different buildings and on the Pike for the purpose of furnishing direct current at different voltages to exhibitors for power purposes. Where possible the direct current has been carried from one building to another in order to minimize the number of motor-generators and the attendant complications. That required service might be furnished on this plan it was found necessary to install the following sets:

In Machinery Building, one 200 k. w. 125-volt motor-generator and one 300 k. w. 500-volt rotary converter. These units with the 400 k. w. 250-volt Fort Wayne generator, supply direct current to the Machinery, Transportation, Forestry, Fish, Game and Agricultural Buildings. A section of the Pike is also supplied with a part of the 500-volt current.

In Electricity Building, one 150 k. w. 500-volt rotary converter and two 150 k. w. 125-volt motor-generator sets. These units also supply the Varied Industries Building.

In Educational Building, one 75 k. w. 500-volt rotary and two 250 k. w. 125-volt motor-generator sets. These units also supply the Manufacturers' Building.

In Mines Building, one 500-volt rotary and two 125-volt motor-generator sets. These units also supply Liberal Arts, Government and Fisheries Buildings.

In West Cascades, two 150 k. w 125-volt motor-generator sets, supplying current for elevators and motors in Festival Hall and Restaurant.

In Terminal House on the Pike, one 150 k. w. 500-volt rotary and two 150 k. w. 125-volt motor-generators. These units are used to supply current to motors and arc lamp projectors used in connection with concessions.

The following classes of service are available in the different buildings:

Government Building:
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 3 wire system.
Series Alternating 50 cycle for Arc Lighting.

Mines and Metallurgy Building:
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.
Series Alternating 50 cycle for Arc Lighting.

Liberal Arts Building.
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.
Series Alternating, 50 cycle, for Arc Lighting.

Education Building:
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.
Series Alternating, 50 cycle, for Arc Lighting.

Manufactures Building:
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.
Series Alternating, 50 cycle, for Arc Lighting.

Electricity Building:
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.
110 volt Alternating Current, 60 cycle, 2 phase, 4 wire system.
6600 volt Alternating Current, 25 cycle, 3 phase, 3 wire system.
2200 volt Alternating Current, 60 cycle, 2 phase, 4 wire system.
2200 volt Alternating Current, 50 cycle, 3 phase, 3 wire system.
Series Alternating, 50 cycle, for Arc Lighting.

Varied Industries Building:
110 volt Direct Current }
220 volt Direct Current } 3 wire system.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system
Series Alternating, 50 cycle, for Arc Lighting.

Machinery Building:
110 volt Direct Current.
220 volt Direct Current.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system
Bullock Multi-voltage, 90–160–250 volt, Direct Current.

Transportation Building:
110 volt Direct Current.
220 volt Direct Current.
500 volt Direct Current.
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.
Series Alternating, 50 cycle, for Arc Lighting.

Agriculture Building:
110 volt Alternating Current, 25 cycle } single phase, 3 wire system.
220 volt Alternating Current, 25 cycle }
500 volt Direct Current.
Series Alternating, 50 cycle, for Arc Lighting.

Horticulture Building:
110 volt } 25 cycle, single phase, 3 wire systems.
220 volt }
Series Alternating, 50 cycle, for Arc Lighting.

Forestry, Fish and Game Building:
110 volt Alternating Current, 25 cycle } single phase, 3 wire system.
220 volt Alternating Current, 25 cycle }
500 volt Direct Current.
Series Alternating, 50 cycle, for Arc Lighting.

Art Galleries:
220 volt Alternating Current, 25 cycle, single phase, 2 wire system.

Festival Hall:
110 volt Alternating Current, 25 cycle, 3 phase, 4 wire system.

It is difficult to appreciate the vast amount of work required to distribute the energy as outlined in the foregoing list. The circuits for each class of service were run entirely around each building in order that cut in services might be quickly made when applied for by exhibitors.

Mining and Metallurgy Building, at Night.

The most striking feature is the decorative lighting of the buildings. In this work an immense amount of money was expended and the results obtained fully warranted it. Every building is outlined with incandescent lights and the important architectural features brought out, rendering the buildings as pleasing and imposing as in the day time. The Festival Hall with its wings formed by the

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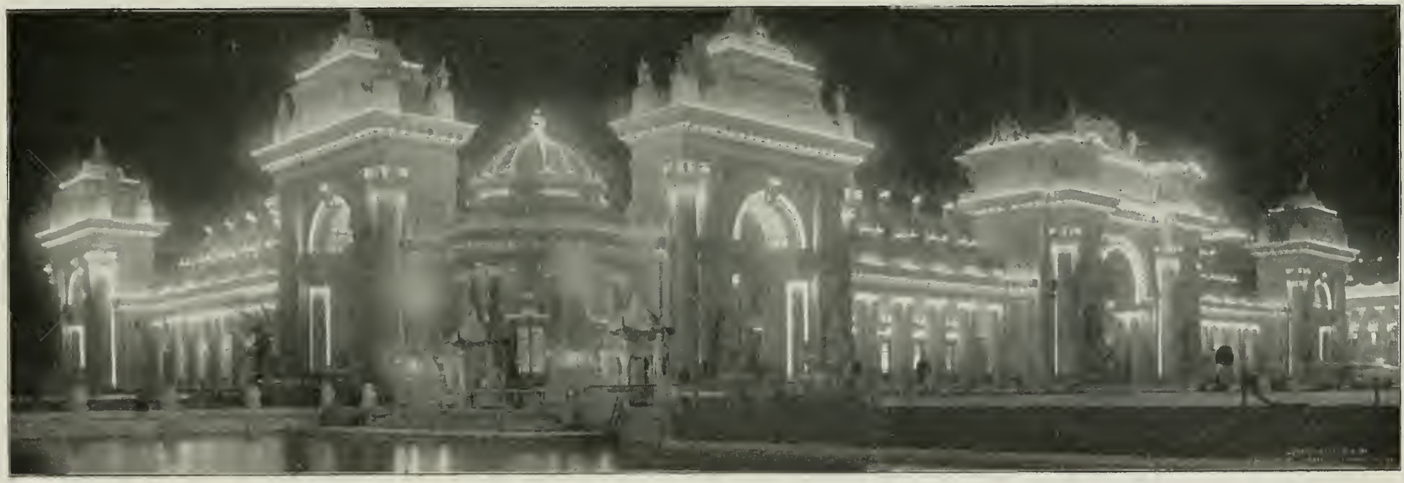
The illustrations of buildings as they appear at night are reproduced by permission of the Official Photograph Co., to whom thanks are hereby returned.



Manufacturers' Building, at Night.

Terrace of the States, and flanked by the Electricty and Educational Buildings, having the Cascades as a ground work and the Grand Basin as a mirror for the reflection of innumerable lights, makes a picture that cannot be adequately described, and must be seen to be appreciated. Its like has never been seen and it is doubtful if an equal amount of money will ever again be expended for the purpose of decorative lighting.

Any direction in which one turns the eye is met with practically the same spectacle, varied by the arrangement and architecture of the different buildings—there is no impression of sameness as one would imagine. Arc lights have been carefully arranged and do not appear in any part of the grounds to the detriment of the soft effect given by the use of incandescent globes. The approaches and bridges over the lagoons are tastefully outlined and other ground lights on ornamental poles are used to maintain the general lighting effect.

Festival Hall and the Terrace are wired in triplicate for three colors of lights and by July 1st the beautiful effect of lighting on the entire Art Hill may be enhanced by a change of colors fading from white into emerald and emerald into crimson. This effect is to be accomplished by the use of water rheostats placed in the primary leads and electrically operated, and that which savors of magic to the unitiated is only the application of comparatively simple apparatus.

The cascades and fountains which may be termed an electrical demonstration, represents one of the strongest efforts of the artists to produce an effect of nature and permanence. While the effect of the cascades is but little enhanced by any lighting that conditions permitted, it serves to bring out the outline and make apparent the flow of water, which otherwise would not be appreciated. The water is pumped 92 feet to the top of the cascades by means of centrifugal pumps, the largest ever built, each direct connected to a 2,000 h. p. 6,600-volt induction motor. There are three of these pumps and motors placed in a line and located under the east cascade. There is no outward evidence of these units and few people know by what force or means the magnificent spectacle and challenge to nature is produced. No similar equipment was ever installed for any purpose and it serves as an example of the efforts made by the exposition to demonstrate new and interesting methods.

It would be possible to speak indefinitely without repetition if we were inclined to consider details. There is only one way to gain even a fair idea of the magnitude of the electrical features and that is to visit the exposition. When those of you who do visit the exposition and note that some detail is not carefully carried out or the arrangement of some apparatus might have been better, you

Palace of Liberal Arts, at Night.

will please remember that time is an important element in all work of this character and we had less time than anything else. Consider that on December 1st only one engine and four boilers were on the ground, not a building was one-third wired and some had not been started, not a foot of cable was installed or transformer in place, that the plans had not even been completed, and with all this work and much more to do, it is not strange that some things were not done in theoretically the best manner.

I want to acknowledge my indebtedness to H. F. Smith, assistant mechanical engineer, and W. M. Dixon, assistant electrical engineer, who were my close advisers and assistants in the work. They both proved their ability in every way, and it was as much due to them as myself that one minute and nine seconds after the signal was given by President Roosevelt, the entire machinery was started and water pumped over the cascades and at 7:30 p. m. on the opening day, the entire decorative lighting was turned on at the exact schedule time.

When this paper was read to the Electrical Section, W. S. E., many lantern slide illustrations were shown, which have not been reproduced. These include some views of work done, the installation of electric cables, etc., etc., and explanations made, as they were shown. by the author of the paper.

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each applicaton, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

EXCURSION TO KANKAKEE, ILL.,

AUGUST 12, 1904.

The members of the Western Society of Engineers, with their families and friends had a pleasant excursion to Kankakee, Ill., Aug. 12, 1904.

Through the courtesy of the Illinois Central Railroad Co., a special train was provided for the trip.

Mr. J. B. Marsh, of Des Moines, Iowa, is the contractor for a reinforced concrete bridge across the Kankakee River, at Washington avenue, and it was to see this work under construction that the excursion was planned. The illustrations give some idea of the bridge, which is being built for the City of Kankakee, Ill. The bridge consists of seven (7) semi-eliptic arches, each of 73 feet, clear span, and with a rise of 8 feet 5 inches. The bridge is 46 feet wide, will have two footwalks, and is to carry a double track electric railway. The total length of the concrete construction is 593 feet, and between 5,000 and 6,000 cubic yards of concrete will be used in the structure.

The concrete of the arches is of a 1-2-4 mixture, of the spandril walls is a 1-3-6 mixture, while the piers and abutments are of concrete of 1-3½-7 mixture.

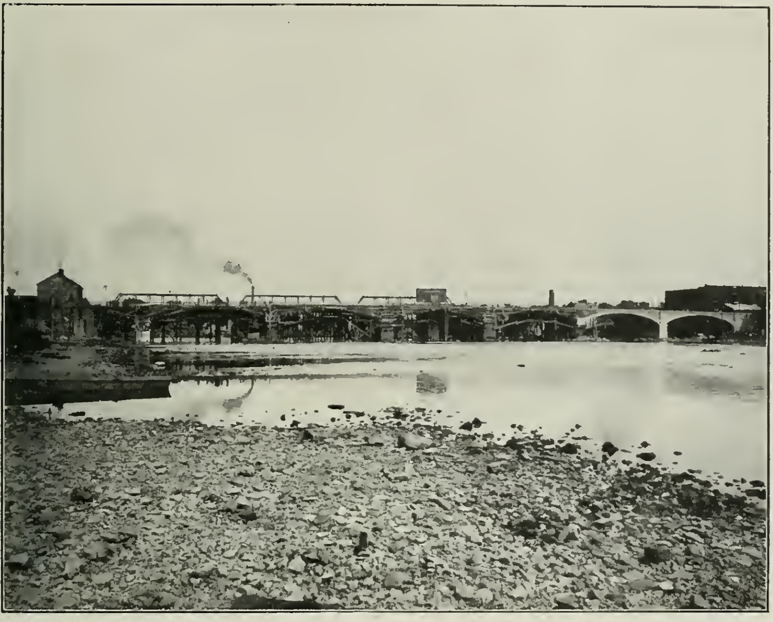
The crown of the arch is 16 inches thick, but the reinforcement, of Thacher bars, 1⅛-inch diameter, is spaced 10 inches c. to c. vertically, at the crown of the arch, with a greater distance at the abutments.

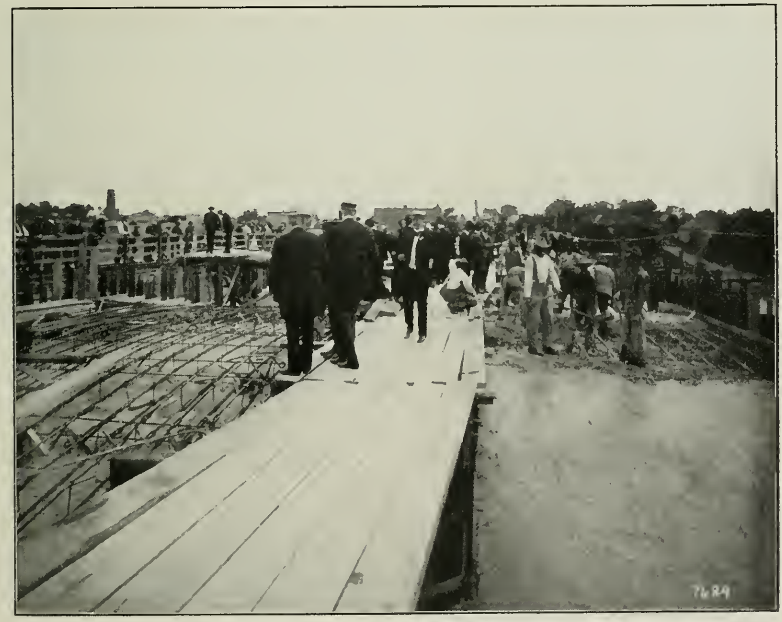
The bars are 17 inches c. to c. across the width of the bridge, and the upper and lower series of bars are tied together at frequent intervals. Mr. Marsh has been very fortunate thus far, in the weather conditions, and has been able to push the work forward in a commendable manner. The methods of handling the material, and the organizatian of the working force, are admirable, and contribute in no small degree to the excellent progress of the work.

On the arrival of the special train at Kankakee the party was met by Mr. Marsh and many of the city officials, who did every thing to make it pleasant for their visitors.

A trolley ride around the city, out to Bradley and beyond, was taken, and dinner was furnished at two of the hotels, after which came the inspection of the concrete bridge.

Near the bridge a concrete dam, for water power, was under construction, of which Mr. T. T. Johnston, M. W. S. E., is the engineer. After looking over the bridge many of the party were taken to the "Eastern Hospital for the Insane," a state institution, and one of the largest in the United States, but time was too short to permit of much examination of the buildings and beautiful grounds. — Return was made to Chicago before 5 o'clock.





Washington Ave. Bridge, Kankakee, Ill.
Reinforced Concrete.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—April 6, 1904.

A regular meeting of the Society (No. 520) was held on the 6th of April and was called to order at 8:20 p. m. with President Parkhurst in the Chair and about 140 members and guests present

The Secretary read the Minutes of the meetings held March 2d, 16th, 18th and 30th, which were approved.

A report from the Board of Direction announced the election of the following persons into membership, at their regular meeting, held April 5th, under their respective grades:

B. F. Affleck, Chicago, Associate.
Henry M. Byllesby, Chicago, Active.
Otto E. Osthoff, Chicago, Active.
Arthur S. Huey, Chicago, Associate.
Arthur M. Morgan, Chicago, Active.
P. B. Woodworth, Chicago, Active.
W. B. Hale, Chicago, Active.
Myron M. Fowler, Chicago, Junior.
Albert Scheible, Chicago, Active.
Albert L. Tucker, Chicago, Active.
Hardy P. Kieffer, Chicago, Associate.
James R. Cravath, Chicago, Active.
Horace G. Dimick, Chicago, Associate.
Fred. A. Rogers, Chicago, Active.
J. G. Wray, Chicago, Active.

Also that the following list of new applications had been received:

Ellis C. Soper, Chicago.
George H. Lukes, Chicago.
Van Rensselaer Lansingh, Chicago.
Harry R. King, Chicago.
Frederick Roeber, Eagle Grove, Iowa.
Eugene Rummler, Chicago.
Francis Raymond, III, Chicago.
S. G. McMeen, Chicago.
Charles J. Carlsen, Chicago.
Fred. M. Davis, Chicago.
Oscar Linder, Chicago.
James L. Mills, Chicago.
A. O. Kuehmsted, Chicago.
S. M. Zurawski, Chicago.
Henry P. Clausen, Chicago.
Guy E. Ditzler, Chicago.
Elwood W. Jewell, Chicago.
Clarence H. Norwood, Chicago.
R. F. Schuchardt, Chicago.
Austin Kimble, Chicago.
Charles H. Smoot, Chicago
Hayward Cochran, Chicago.
Hugh S. Carr, Constantine, Mich.
Charles E. De Crow, Chicago.
Gustav A. Roth, Chicago.
Charles H. Roth, Chicago.
Henry W. Young, Chicago.
Wm. H. Slingluff, Chicago.
Edward Dvorak, Chicago.
Geo. R. Brandon, Chicago.
De Witt C. Tanner, Chicago.
Geo. N. Eastman, Chicago.
F. M. Holbrook, Chicago.

John H. Sass, Downer's Grove, Ill.
Byron Layton, Chicago.
Edward M. Miller, Chicago.
Carl Wiler, Chicago.
LeRoy W. Stanton, Cleveland, Ohio.
Samuel F. Joor, Chicago.
Walter T. Ray, Chicago.
Lyford C. Bradley, Chicago.
Robert H. Merrill, Grand Rapids, Mich.
Durl P. Ruger, Chicago.
P. A. Fisker, Chicago.

A telegram from Professer Howe was read, stating that it would be impossible for him to be present to present in person his paper on Reinforced Concrete.

The Secretary announced that an invitation had been extended to the Western Society of Engineers by the Chicago Architectural Club, to attend an illustrated lecture by Victor Falkenau on "The Baltimore Fire and its Lessons, with special reference to the High-Pressure Water System," at the Art Institute; the date to be announced later.

Prof. W. H. Hatt was then introduced, who abstracted his paper on "Flexure of Reinforced Concrete Beams," aided by blackboard illustrations.

In the absence of Professor Howe, Mr. Condron read his paper on "Cross-bending Tests on Steel-Concrete Beams." At the conclusion of Mr. Condron's presentation of Prof. Howe's paper, a number of lantern slides were shown, illustrating both papers.

The papers were discussed by Messrs. Schaub, Sherman, A. L. Johnson, Montgomery, Condron, McArdle, Benezette Williams, Professor Talbot and Professor Hatt.

On motion of Mr. C. H. Cartlidge, further discussion was postponed until a subsequent meeting, the date to be announced later.

The meeting adjourned about 10:45 p. m.

EXTRA MEETING—April 20, 1904.

An extra meeting (No. 521) was held in the rooms of the Society on the 20th of April, and was called to order at 8:30 p. m. with Vice President Hotchkiss in the Chair and about 50 members and guests present.

As there was no business to come before the Society, Mr. George E. Ellis was introduced, who presented his paper on "Railroad Signaling." The paper was illustrated by a large number of lantern slides. Written discussion from Mr. Dwight C. Morgan, of St. Paul, was read by the Secretary.

The meeting adjourned about 10:40 p. m.

REGULAR MEETING—May 4, 1904.

A regular meeting of the Society (No. 522) was held Wednesday evening, May 4th, in the rooms of the Society. The meeting was called to order at 8:15 o'clock, with W. L. Abbott, Second Vice President, in the Chair, and about 45 members and guests present.

The minutes of the regular meeting April 6th, and of the meeting of April 20th, were read and approved.

A report from the Board of Direction announced the election of the following persons into membership of the Society:

William E. Reynolds, Chicago, Active.
Samuel A. Rhodes, Chicago, Active.
Harold Almert, Chicago, Active.
Martin L. Brown, Chicago, Associate.
Herbert M. Wheeler, Chicago, Junior.
Alexander W. Mosely, Chicago, Active.
Ellis Clark Soper, Chicago, Junior.
Van Rensselaer Lansingh, Chicago, Active.
Harry R. King, Chicago, Active.
Fredrick Roeber, Eagle Grove, Ia., Active.

Eugene A. Rummler, Chicago, Active.
Francis Raymond, III, Chicago, Associate.
Samuel G. McMeen, Chicago, Active.
Charles J. Carlsen, Chicago, Active.
A. O. Kuehmsted, Chicago, Associate.
S. M. Zurawski, Chicago, Active.
Henry P. Clausen, Chicago, Active.
Guy E. Ditzler, Chicago, Active.
Elwood W. Jewell, Chicago, Active.
C. H. Norwood, Chicago, Associate.
R. F. Schuchardt, Chicago, Active.
Hayward Cochrane, Chicago, Active.
George R. Brandon, Chicago, Active.
Frederick M. Holbrook, Chicago, Active.

Also that the following new applications had been received:

Thos. G. Grier, Chicago.
Howard Brooks, Durango, Mexico.
James T. Walsh, Chicago.
James A. S. Redfield, Belle Plain, Iowa.
Charles M. Denise, Chicago.
George W. Brady, Chicago.
Alex M. Blumenthal, Chicago.
Bernard F. Sieben, Chicago.
Frederick A. Watkins, Chicago.
Hermann Haussmann, Jr., Chicago.

A letter from Prof. W. K. Hatt, Chief, Section of Timber Tests, Bureau of Forestry, U. S. Department of Agriculture, dated April 16th, was presented, including a draft of some resolutions to be submitted to the Society relative to the work of investigations into timber, now under operation in the Bureau of Forestry, as follows:

"WHEREAS, The Western Society of Engineers, with a membership of about 750, recognizes the value of the timber tests now being carried on by the Bureau of Forestry, United States Department of Agriculture, in determining the structural value of the various species of commercial timbers of the United States, and the value of the investigations being made as to the best methods for handling and preserving timbers; and

"WHEREAS, It further recognizes the application of the results of this work in the design of safe and economical structures; in the preservation of existing supplies of timber; and in making possible the conservative administration of forest tracts in the general interest of forestry;

"*Be it resolved*, That this Society hereby records its appreciation of the work thus far completed, and urges the Honorable Secretary of Agriculture to request Congress to make such appropriations as may be necessary to carry out the investigations in the most effective and satisfactory manner.

"The Secretary of this Society is hereby instructed to send a copy of these resolutions to the Honorable Secretary of Agriculture, and to the Forester of the United States Department of Agriculture."

On motion of Mr. Finley, duly seconded and carried, the resolutions were adopted.

Dr. Wm. B. Phillips, Director of the University of Texas Mineral Survey, was then introduced, who presented his paper on "Texas Coal, Lignite, Oil and Asphalt," the paper being illustrated by many lantern slides.

Discussion followed from Messrs. W. L. Abbott, Schrader, Finley, DeWolfe, Warder, Layfield, Dimick, Billow, Flather and Phillips.

The meeting adjourned about 10 p. m.

EXTRA MEETING—May 11, 1904.

An extra meeting of the Society (No. 523) was held Wednesday evening, May 11th, in the rooms of the Society. The meeting was called to order at 8:20 p. m., with Mr. W. H. Finley, Past President, in the Chair, and about 35 members and guests present.

Mr. Geo. S. Rice, M. W. S. E., presented his paper on "The Use of Steel for Coal Mine Tipples, and a classification of Same." The paper was illustrated by lantern slides, and discussion followed from Messrs. Warder, Liljencrantz, J. F. Jackson, Finley, Schaefer, Spielman and Rice.

The meeting adjourned about 10:15 p. m.

REGULAR MEETING—June 1, 1904.

A regular meeting of the Society (No. 524) was held in the Society Rooms on the 1st of June, and was called to order at 8:20 p. m. with Past President Finley in the Chair, with about 100 members and guests present.

The Secretary read the Minutes of the meetings held May 4th and 11th which were approved.

A report from the Board of Direction announced the election of the following persons into membership, at their regular meeting held May 31st, under their respective grades:

Oscar J. West, Chicago, Active.
George H. Lukes, Evanston, Ill., Active.
Byron Layton, Chicago, Active.
Le Roy W. Stanton, Cleveland, Ohio, Active.
Thomas G. Grier, Chicago, Active.
Howard Brooks, Velardena, Durango, Mexico, Active.
James A. S. Redfield, Belle Plain, Iowa, Active.
Chas. M. Denise, Chicago, Active.
Herman Haussman, Jr., Chicago, Junior.

Also that the following new applications had been received:

Edwin F. Pierce, Chicago, Active.
Kempster B. Miller, Chicago, Active.
John Harper, Evanston, Ill.
Chason W. Brooks, Chicago, Junior.
Lewis M. Martin, Anita, Iowa, Junior
William C. Porter, Laurel, Miss., Active.

On motion of Mr. Liljencrantz this report was accepted.

Mr Grant offered a resolution that the meetings of the Society be suspended during July and August, which motion was duly carried.

The subject for the evening was further discussion of the papers by Professors Hatt and Howe on Reinforced Concrete, presented before the Society April 6th.

Discussion was presented by Messrs. Jas. J. Harding, Fulton, Bainbridge (read by Mr. Condron), L. P. Mensch, C. H. Cartlidge (read by Mr. Eldridge), and William Sooy Smith.

The meeting adjourned about 10:15 p. m.

ELECTRICAL SECTION.

SECOND MEETING—June 24, 1904.

The second meeting of the Electrical Section of the Society was held in the audience room Friday evening, June 24th. (This was an extra meeting (No. 525) of the Society.) The meeting was called to order at 8:30 o'clock, with Chairman W. B. Hale in the Chair, and about 35 members and guests present.

The Chairman stated that it had been thought advisable by the Board of Direction and the Executive Committee of the Electrical Section that some special rules should be prepared as a line of procedure for future work, and that such rules had been prepared by the Executive Committee of the Electrical Section, assisted by the Secretary. These rules were presented but action was defered until a later meeting.

Mr. E. B. Ellicott, M. W. S. E., City Electrician of Chicago, and Chief Mechanical and Electrical Engineer of the Louisiana Purchase Expositon, St. Louis, was then introduced who presented his paper on "Some of the Electrical Features of the Exposition," this being illustrated by lantern slides.

The meeting adjourned about 9:40 p. m.

J. H. Warder, *Secretary.*

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the Journal for April, 1904, we have the pleasure to report the following additions to the library and gifts from donors named:

NEW BOOKS PURCHASED.

Abady, "Gas Analyst's Manual." 1902.
Abbott, "Telephony," Part 1—"Location of Central Offices." 1903.
'' '' '' 2—"Construction of Underground Conduits."
'' '' '' 3—"The Cable Plant."
'' '' '' 4—"Construction of Aerial Lines."
Ayrton, "The Electric Arc."
Bell, Louis, "Electric Power Transmission." 1901
'' '' "Power Distribution for Electric Railways." 1900.
Billings, "Ventilation and Heating." 1893.
Bodmer, "Hydraulic Motors and Turbines." 1893.
Boulger, "Wood—A Manual of Natural History and Industrial Application of the Timbers of Commerce." 1902.
Chatelier and Boudouard, "High-temperature Measurements." 1901.
Clark, "Building Superintendence." 1903.
Considere, "Reinforced Concrete." 1903.
Harbord, "Metallurgy of Steel." 1903.
Hawkins, "The Dynamo." 1903.
Hempel, "Methods of Gas Analysis." 1902.
Herrick, 'Practical Electric Railway Hand-book." 1901.
Hiorns, "Iron and Steel Manufacture." 1902.
Houston and Kennelly, "Electric Heating." 1895.
'' '' '' "Electric Incandescent Lighting." 1902.
'' '' '' "Electric Arc Lighting." 1902.
'' '' '' "Electric Street Railways." 1902.
Houston, "Dictionary of Electrical Words, Terms and Phrases." 1898.
Hutton, "The Gas Engine." 1903.
Jones, "Machine Design, Part 1—Kinematics of Machinery." 1903.
'' "Machine Design, Part 2—Form, Strength and Proportions of Parts." 1904.
Keep, "Cast Iron." 1902.
Lyndon, "Storage Battery Engineering." 1903.
Maurer, "Technical Mechanics." 1903.
Maycock, "Electric Lighting and Power Distribution." 1902-1903. Vols. I and II.
Parham and Shedd, "Shop and Road Testing of Dynamos and Motors." 1901.
Phillips, "Engineering Chemistry." 1902.
Pratt, "American Railways." 1903.
Pratt and Alden, "Street Railway Roadbed." 1898.
Smith, "Proof-Reading and Punctuation." 1903
Snyder, "Chemistry of Plant and Animal Life." 1903.
Swenson and Frankenfield, "Testing of Electro-Magnetic Machinery, etc." 1904.
Thorp, "Outlines of Industrial Chemistry." 1903.
Wagner, "Manual of Chemical Technology." 1900.
Walker, "Introduction to Physical Chemistry." 1903.
Wilson, "Irrigation Engineering." 1903.

MISCELLANEOUS GIFTS.

American Boiler Manufacturer's Association, Proceedings 10th annual convention at St. Louis, 1898. Pamphlet.
Brown, Chas. C., Indianapolis, Ind., Directory of Cement Industries. 1904.

Burlington, Vermont, City of, Annual Report Health Officer for 1903. Pamphlet,
Camp, W. M., Chicago, Blue Book of American Shipping, 1899; 1 bound volume.
Canadian Society of Civil Engineers, Montreal. Two pamphlets:
  Constitution and List of Members, 1904.
  Report Annual Meeting, 1904.
Carnegie Institution of Washington, D. C , two pamphlets: Year Book No. 1, 1902;
  " " No. 2, 1903.
Chicago Board of Trade, Year Book for 1903. Cloth.
Commercial Club, Chicago, Pamphlet, "The Street Paving Problem of Chicago," by John W. Alvord. 1904
Cooley, Lyman E., M W. S. E., Chicago; cloth bound volumes, U. S. Geological Survey Reports for 1885-6, 1886-7.
Corthell, Elmer L., M. W. S. E., New York, "The Tampico Harbor Works, Mexico." Pamphlet.
Crerar Library, Chicago, pamphlet; 9th annual report for 1903.
Elmer, H. N., M. W. S. E., Chicago, sundry books:
  1 vol. quarto cloth, U. S. Geological Survey, 21st annual report, 1899-1900, Part IV Hydrography.
  7 vols. octavo cloth, Reports Chief Engineer U. S. A , 1900, parts 1-7 inclusive.
  6 vols. cloth, Reports Chief Engineer U. S. A., 1901.
  2 vols. cloth, Reports Chief Engineer U. S. A., 1902, Parts I and III.
  1 vol. cloth, Indiana State Geological Report, 1900.
  2 vols, cloth, Indiana, Dept. of Statistics, 5th report 1893-4 and 8th report, 1899-1900.
 Sundry pamphlets:
  Copies of Journal W. S. E.
  Report, State Bureau of Mines, Colorado, 1897.
  Report, 13th convention R. R. Supts. Bridges and Buildings, 1903.
Ewald, Frank G., M W. S. E., Springfield, Ill., two volumes, flexible morocco:
  Report R. R. & W. Commission of Illinois for 1903.
  Decisions and Opinions of the R. R. & W. Commissioners of Illinois, Vols. I and II, 1889-1903.
Fritch, L. C., Sec'y, American Railway Engineering and Maintenance of Way Association, seven pamphlets:
  Bulletins 28, 35, 39, 46. 47, 48; and Vol. II, No. 1, Nov., 1900.
Huyette, M. C., Chicago, one cloth bound volume, "Coal is King." 1903.
Institution of Civil Engineers, London, pamphlet; Minutes of Proceedings, 1903-4 Vol. CLV.
Jackson, Geo. W., M W S. E , Report of High Pressure Water System. Pam.
Jacobs, Chas. M., Chief Engineer Penna., N. J. & N. Y. R. R. Co., North River Division; Contract Drawings, Specifications, etc.
Jamieson, J. A., Montreal, pamphlet, "Grain Pressures in Deep Bins." 1903.
Litten, Nelson L., Chicago, two bound volumes, "Acetylene Journal;" Vols. 3 and 4, 1901-2; 1902-3.
Lowell, Mass., Water Board, 31st Annual Report to City Council, City of Lowell, for 1903. Pamphlet.
Lynn, Mass., Public Library, J. C. Houghton, Librarian, 41st Annual Report for 1903, of Trustees, Librarian and Treasurer.
Massachusetts Institute of Technology, Boston, pamphlets.
  Courses in Chemistry and Chemical Engineering, 1903.
  Dept. of Mechanical Engineering, 1902.
  Dept. of Naval Architecture, 1902.
  Annual Report of President and Treasurer, Dec. 9, 1903.
Massachusetts Railroad Commissioners, two bound volumes and three pamphlets; Reports 1876, 1877, 1887, 1890, 1903.
Metropolitan Water and Sewage Board, Wm. M. Davenport, Sec'y; 3d Annual Report, 1903. Cloth.
New Jersey, State of, "Report of Commissioner of Public Roads for 1903." Bound volume.
New Jersey, State of, J. Willard Morgan, Comptroller, cloth bound volume, Annual Statements of Railroad and Canal Companies of New Jersey, for 1903.

New York, City of, Report of Commissioners of Accounts, "Asphalt Paving," February, 1904. Cloth.

Noble, Alfred, Chief Engineer, East River Division, Penna., New York & Long Island R. R. Co , New York City, Contract Drawings, Specifications, etc.

Ohio State Geologist, E. Orton, Jr., cloth bound volume, Bulletin No. 1, Series IV, Geological Survey of Ohio, 1903, Oil and Gas, by Bownocker.

Providence, R. I., City of, Annual Report of City Engineer for 1903. Pamphlet.

Ripley, Joseph, Gen'l. Supt., St. Mary's Falls Canal, pamphlet: "Statistical Report of Lake Commerce Passing Canals at Sault Ste. Marie, Mich , and Ontario during 1903."

Royal Engineers Institute, Chatham, "The Blacksmith's Work," by Major R. F. Sorsbie.

Sanitary District of Chicago, Board of Trustees:

Proceedings for the year 1903—half leather bound.

Annual Report of Engineering Department, 1903. Pamphlet.

Report on Organization, Resources, Constructive Work, Method and Progress. Pamphlet.

Simmons, W. C., Providence, R. I., Report, Commissioner of Dams and Reservoirs, State of Rhode Island and Providence Plantations, January, 1904. Cloth bound volume.

Tratman, E. E. R., M. W. S. E., Chicago:

Report, Commissioner of Public Roads, State of New Jersey, 1903. Cloth bound volume.

Pamphlets:

Ninth Annual Report, Crerar Library, for 1903.

Report, Water Power of the Rock River, by D. W. Mead.

U. S. Geol. Survey, Bulletin No. 225, Contributions to Economic Geology. 1903.

Union Internationale de Tramways et de Chemins de fir d' interet local. (Treizieme Assemblee" Generale at Vienne, Sept. 11, 1904)

Report, General Manager of Railways for year 1903, Cape of Good Hope.

Proceedings, 21st annual convention, Roadmaster and Maintenance of Way Association, 1903.

Pamphlet No. 11, National Municipal League, "A Year's Disclosure and Development," 1904.

Report, Water Boring on the Cape Government Railways for 1903. Cape of Good Hope.

Bureau of the Census, Bulletin No. 9, Mines and Quarries.

University of Chicago Press, Catalogue of the Publications of the University of Chicago Press, 1903. Pamphlet.

University of Michigan, Engineering Society, pamphlet, "The Michigan Technic, 1904."

Wiederhold, H., Philadelphia, Lecture on Asphalt, May, 1904. Pamphlets.

Winona Assembly and Summer School Association, "Its History, Method and Future," by Thos. Kane, 1904. Pamphlet.

Wisconsin Geological and Natural History Survey, Madison, E. A. Birge, Director, two pamphlets:

"Preliminary Report on Soils and Agricultural Conditions of North Central Wisconsin," by S. Weidman, 1903.

"The Plankton of Lake Winnebago and Green Lake," by C. Dwight Marsh, 1903.

GOVERNMENT PUBLICATIONS.

U. S Civil Service Commission, Washington, D. C., "20th Annual Report, July 1, 1902, to June 30, 1903." Cloth.

U. S. Department of Agriculture, Bureau of Forestry, sundry pamphlets:

"Forest Fires in the Adirondacks in 1903."

"Recent Progress in Timber Preservation," by Von Schrenk.

"The Relation of Forests to Stream Flow," by Toumey.

"The Planting of White Pine in New England," by Kempton.
"Cross-tie Forms and Rail Fastenings, with Special Reference to Treated Timbers." Von Schrenk.
"Building Sand-Clay Roads in Southern States." Spoon.
"Progress of Road Building in the Middle West."

Interstate Commerce Commission, Washington, D. C., 17th Annual Report for 1903. Cloth.

U. S. Department of Agriculture, Year Book for 1903. Cloth.

U. S. Geological Survey, Department of the Interior, pamphlets:
"Water Supply and Irrigation Papers, Nos. 87-94 inclusive."
Bulletin No. 223, "Gypsum Deposits in the United States." 1904.
" " 224, "A Gazetteer of Texas," by Gannett. 1904.
" " 225, "Contributions to Economic Geology," 1903.
" " 226, "U. S. Geologic Survey, its Origin, Development, Organization, and Operations." 1904.
Bulletins Nos. 228, 229, 230, 231.

Professional Papers:
No. 11—Clays of the United States East of the Mississippi River, by Ries. 1903.
No. 12—Geology of the Globe Copper District, Arizona. 1903.
No. 16—Carboniferous Formations and Faunas of Colorado. 1903.
No. 17—Geology and Water Resources of Western Nebraska. 1903.
No. 18—Chemical Composition of Igneous Rocks. 1903.
No. 19—Contributions to the Geology of Washington. 1903.
No. 20—A Reconnoissance in Northern Alaska in 1901.
No. 21—Geology and Ore Deposits of the Bisbee Quadrangle, Arizona.
No. 22—Forest Conditions in the San Francisco Mountains Forest Reserve.
No. 23—Forest Conditions in the Black Mesa Forest Reserve, Ariz.
No. 28—Superior Analyses of Igneous Rocks.

U. S. War Department, Washington, D. C., Wm. D. Beach, Report of the Chief of Ordnance, 1903. Cloth.

U. S. Department of Commerce and Labor, Bureau of Standards, S. W. Stratton, Director. Pamphlets.
"Verification of Standards and Measuring Instruments 1-6 inclusive."
Circular of Information of the National Bureau of Standards No. 4 (Table of Equivalents of the Customary and Metric Weights and Measures.)
Annual Report of the Director of the National Bureau of Standards for the fiscal year ending June 30, 1903.

U. S. Department of Commerce and Labor, Bureau of the Census. Pamphlets.
Bulletin No. 1—Population of the Philippines, 1903.
" " 2—Climate of the Philippines.
" " 3—Volcanoes and Seismic Centres of the Philippine Archipelago.
Bulletin No. 9—Mines and Quarries.
Occupations at the Twelfth Census, 1904. Cloth bound.

Smithsonian Institution, Washington, D. C., cloth bound volumes:
"Meteorological Tables, 1897."
"Geographical Tables, 1897."
"Physical Tables."

EXCHANGES.

American Society for Testing Materials, Vol III. Proceedings of 6th Annual Meeting at Delaware Water Gap, Pa., July, 1903. Pamphlet.

American Society of Heating and Ventilating Engineers, New York, Transactions for 1903. Bound volume.

Association of Civil Engineers, Cornell University, Transactions for 1904. Pam.

American Electrochemical Society, Philadelphia, Vol V. Transactions 5th General Meeting 1904. Bound volume.

American Institute of Electrical Engineers, New York, Vol. 20, Transactions July 1st to December 31st, 1902. Pamphlet.

Iowa Engineering Society, Des Moines, Iowa, Proceedings 16th Annual Meeting, January, 1904. Pamphlet.

Junior Institution of Engineers, London, Vol. XIII. Transactions session twenty-two, 1902-3. Bound volume.

Lake Superior Mining Institute, Marquette, Mich. 9th Annual Report for 1903. Vol IX. Pamphlet.

Ohio State Board of Health, Columbus 17th Annual Report for year ending 1902. Pamphlet.

Royal Engineers Institute, Chatham, Transactions for 1903. Cloth.

Society of Engineers, London, Transactions for 1903 and General Index. Pam.

TRADE CATALOGUES.

Crosby Steam Gage & Valve Co., Chicago. Cloth bound catalogue, 1904.

Chandler & Taylor Co., Indianapolis, Catalogue Enclosed Automatic Engines—Series E-1.

Dietzgen, Eugene, Chicago, Catalogue and Price List of Drawing Materials, Surveying Instruments, etc., 1904.

General Electric Co., Schenectady, N. Y., "Electric Mine Locomotives," Catalogue No. 1045, February, 1904.

Jeffrey Mfg. Co., Columbus, Catalogue Jeffrey Water Elevators.

National Paint Works, Williamsport, Pa., "Review of Technical Paints for the Protection of Metal Surfaces."

Vulcanite Portland Cement Co., Philadelphia. Catalogue 1904.

BOOK NOTES.

The Slav Invasion and the Mine Workers. Frank Julian Warne. Ph. D. Philadelphia. J. B. Lippincott & Co. 12mo. Cloth. 190 pages and map. $1.00.

The dominant purpose of political and social science to-day is a first hand investigation of facts; and its spirit that of willingness to recognize the existence of a fact of our social order as such, even when it chances to be a newly evolved institution without origin in or sanction from fundamental law. Public opinion is following or perhaps in some cases preceding the special student. We are willing to admit now that the primary and the political convention are as much a part of the real constitution of our nation as if they had been incorporated into the written document which is the supposititious basis of all our institutions. And in another field we are almost willing—and should be quite willing—to give recognition to certain other institutions which are elements of our present day social order of a very real sort ; that is the trades-unions and the associations of employers; the latter being quite as legitimate as the former and, as a matter of fact, the product of the same industrial conditions.

This pragmaticism, to borrow a popular word from contemporary philosophy, which means the theory that "gets results," is the characteristic quality of the many studies of social and economic conditions which are being published now. Among these, Dr. Warne's book on the industrial conflict in the anthracite coal fields is to be classed. An indication of the practical quality of this sort of writing one finds the title of the book itself, where the term "Slav" is used in its local popular sense, including a very heterogeneous grouping of races, among the Italians, Lithuanians, Austrian Germans and other Central European peoples quite distinct from the Slavs proper. But except for its picturesqueness this title has little to recommend it. The conflict, the story of which is the subject matter of the book, is industrial primarily, not racial. The vast horde of Central Europeans which came to the coal fields in the eighties and nineties—amounting in fact to an invasion—did much by their cheapness and low standards of living to aggravate the already existent difficulties between labor and capital ; but the invasion did not in any radical sense change conditions. The English speaking workers were as a result almost entirely driven out of the southern, the Schuylkill fields, and were for a time completely demoralized throughout the entire Anthracite region. But, as the course of the narrative shows, the labor organizations, at first thrown into utter confusion by the sudden overwhelming influx of so much cheap labor, recovered eventually and profiting by the ignorance and tractability of their fellow workers were able to pursue their policy of organizing all the labor in the anthracite industry with even more success than before. If something is still lost through the low standard of living of the Slav, it bids fair to be regained at no distant period through the remarkable adaptability and susceptibility to education of those semi-barbarous peoples, instances of which the writer cites.

The real theme of the book is the conflict between the workers—English speaking and Slav as well—and the operators and owners of the mines; a conflict which was an inevitable result of free competition and inevitably it seems, in spite of much well meant legislation to prevent it, led to the close confederation of the capitalists on the one hand and a monopoly of labor by the United Mine Workers on the other. War was not to be avoided and it came in 1902 as every one knows, when a strike was inaugurated which is well classed as among "the costliest and most dangerous conflicts that ever threatened the stability of the Government and the peace of the country." The chapters dealing with this period will probably interest the reader most. The author takes the position that the operators put themselves in the wrong at the start by their unwillingness to recognize among their employees the need of the sort of organized action which they demanded for themselves. The criticism seems an eminently just one. The book in fact gives an impartial and very interesting, though necessarily somewhat cursory, account of thirty years of industrial conflict in the Anthracite coal fields; and if in the end the author comes to no very definite conclusion as to what the eventual outcome is to be, that can hardly be wondered at, insomuch as the subject presents a phase of the problem, as yet far enough from solution, which without doubt is the most serious and portentous one that modern democracy has been called upon to face. TRUMAN.

Irrigation Engineering, by Herbert M. Wilson, C. E. Small 8vo. XXIII, + pp. 573; 41 full plates and 139 illustrations, including many half tones. Fourth edition revised and enlarged. John Wiley & Sons, 1903. $4.00.

The recently enacted Reclamation Laws providing for a systematic construction of irrigation works by the United States government has created a demand for a technical knowledge of the principles of irrigation engineering, which this book is intended to supply. The book is divided into Part I., "Hydrography," Part II., "Canals and Canal Works," and Part III., "Storage Reservoirs," and contains a discussion of the fundamental and underlying principles on which successful irrigation works must be based, with a description of their practical applition to extended irrigation works both in this country, Egypt and India.

Theoretical mathematics are largely excluded from this work, and only such practical mathematical formulæ as are indispensable for practical work have been included.

An important and valuable feature of the book is the addition, at the end of each chapter, of a section giving references to various books and periodicals on the subjects discussed.

Although the literature on irrigation engineering in its various branches is quite extended, this is the first comprehensive discussion of the entire subject, under single covers, which has been attempted in this country. The magnitude of the subject is such that no one work can be expected to treat it exhaustively, nevertheless the discussion offered by this treatise offers a very thorough fundamental knowledge of the subject, which, through the references given, can be extended to such a degree as the student or engineer may desire.

The illustrations are well selected, and are of such a nature as to give a thoroughly practical idea of actual construction.

The book will prove of value both to the student and to the practicing engineer who is interested in either the subject of irrigation, or in other branches of water supply engineering. D. W. M.

Types and Details of Bridge Construction. Part I. Arch Spans—Examples of constructed Wooden, Combination, Wrought Iron and Steel Arches for

Highway and Railroad Bridges. By Frank W. Skinner, C. E. McGraw Publishing Co. New York. 6 x 9. Cloth bound, 294 pages. Many illustrations. Price $5.00.

The author deserves much credit for the work, in which he presents a record of the various designs used in constructing arch bridges, both modern and ancient, in wood and in metal. The references given will enable the student to study the designs, given more in detail; but, it is to be regretted that the author did not go into a discussion of the merits and demerits of some of the designs. All engineering work is not perfect, in fact none is; and, the engineer must constantly choose between evils. Here is where the real engineer exercises his skill and judgment; and, after his work is executed, he himself can criticise it, as well as others; so that it is by a process of elimination that we are constantly approaching perfection, but never reach it. It follows that it would hardly be in the domain of one man to review the merits of all of the designs presented, but it is possible to touch upon some of the salient features which should forever be avoided.

For example, the Surprise Creek arch, on page 58, could have been built much cheaper as an ordinary deck span, which would have provided for the excessive grade of 2.2 per cent without destroying the symmetry of the bridge. The work as built has no symmetry, and the shop work involved in this design is at least 25 per cent more than in an arch which has equal arms; and, compared to an ordinary deck span the shop work is at least 50 per cent more, the weights in both cases being about equal. The writer had an opportunity to go into this matter in detail, at the time this structure was under construction, and about the only reason for building an arch in this place, could have been, that an arch was wanted at any cost.

The Menominee arch, on page 38, is a riveted structure throughout, excepting the web members in the two panels on each side of the center panel. Here eyebars are used for the primary members, and adjustable bars for the counters. What argument could possibly be used for such a digression? All good designs avoid adjustable members, especially in these days where V threads must be cut on steel bars, which, in process of upsetting for threads, must be subjected to a doubtful heat treatment. Moreover, this arch could have been built with straight bottom chords, from hinge to crown, and thereby simplifying the shop work, without making the structure more unsightly than it is.

The Rio Grande bridge, on page 66, is an arch with balancing or shore arms at each end. The shore arms are useful in the process of erection, when no false work can be employed in erecting the river arms, but the shore arms should then be disconnected from the river arms, inasmuch as the continuity, when retained, involves a large reversal of stresses, which violates the proper economy of design in the structure. Any one who has gone into the details of calculation in such a design can verify this statement. Moreover, there is nothing to be gained by this continuity after the work is erected. The most notable example of this kind is the Viaur viaduct in France, as given on page 102.

The Niagara arch, for double track railway and highway, on page 88, is the most notable example of a railway arch in this country. The erection of this structure, by the Pennsylvania Steel Company, showed an ingenuity which has rarely been equalled. It should be remembered that this bridge replaced an existing suspension bridge; and was erected as a cantilever, without interrupting traffic. The difficulty encountered in making the ribs of the arch come together at the crown, which is noted and explained by the author, should have been anticipated by the designer, inasmuch as the same difficulty arose in the erection of the Eads Bridge, almost twenty-five years previous.

The Eads Bridge, at St. Louis, on page 157, is the best study, if one wants to know how not to do things, that is offered in the book. As the author says, "it is unique, for it has not been, and never will be, followed as a type for other bridges." Aside from the sub-structure, it seems as if ideas ran riot in evolving this design. It is unique, inasmuch as the work is not structural work, as bridge work is now understood to be, but machine work, and that of the most expensive and complicated kind. Nor can it be excused from the standpoint that our present forms of construction were then unkown, for the Kentucky River Bridge, on the old Cincinnati Southern Railway was then being built about the same time, which embodied practically all of the features of modern structural bridge work.

The Eads Bidge was erected as a cantilever, as was the Niagara arch, and the same difficulty was encountered in both cases in closing the arch ribs; and, in both cases the ribs were closed by a makeshift, so that no man can tell what the fixed load or temperature stresses are in either structure. In the case of the Eads Bridge the closing of the arch ribs was perhaps a trifle more dramatic. After hearalding, through the newspapers, that they were about to close the ribs by packing them in ice. the junction was finally made by means of an adjustable member, or practically by the use of a shim, just as was done at Niagara. To show how crude this operation was, the lever arm used in screwing up the first closing tube broke, dropping one or two men into the river. The remaining tubes were not screwed up so tight, and they let it go at that. In attempting to close up the arch one of the members in the bridge was actually ruptured. This will give some idea of the uncertainty involved in erecting a tube arch on the cantilever principle.*

This difficulty was anticipated in erecting the Niagara Falls and Clifton arch, as described on page 205.

Under plate girder arches, or ribs which are plate girder, the most notable example is the Washington Bridge, page 279. The Main Street Bridge in Minneapolis, page 266, also comes under this class. The latter has developed a serious defect owing to its lack of rigidity, both vertically and horizontally. The lack of vertical stiffness is probably due to the low rise, combined with the light floor used, the latter having lately been loaded down with a buckle plate floor and a heavy paving. The lack of horizontal stiffness is probably due to the fact that the ribs are in vertical planes, instead of inclined to each other. This is a common defect in all similar arches, the Eads Bridge in St. Louis having the same defect.

J. W. SCHAUB.

CHICAGO, August 19, 1904.

TRADE CATALOGUES.

Cochrane Separators. Harrison Safety Boiler Works, Philadelphia, Pa. A. Sorge, Jr. & Co., Chicago, General Western Representatives. Pamphlet 5x7, 90 pages.

This catalogue relates to those power specialties for the separation of oil, water, or other impurities from currents of steam and also from compressed air and ammonia.

They are used on live steam lines to removed entrained water from the steam before it is admitted to the engine cylinder, and are used in the exhaust steam line to remove all oil or grease, so the steam may be used for heating, by contact and condensation, the feed water for the boilers. When placed in lines of pipe conveying compressed air or ammonia, all impurities are removed, whether small particles of grit, oil or water.

The catalogue is finely printed and fully illustrated with tables of the principal dimensions of the several sizes of separators, from that for 1½-inch pipe to 36-inch pipe, and these separators have been built for even as large as 48-inch pipe.

An interesting part of this catalogue is the discussion of the principles governing the separation of oil and water from a passing current of steam, with illustrations to show how this separator differs from the designs of other makers, and why a greater efficiency is thereby obtained.

Incidentally the catalogue shows the Cochrane feed water heater, of which the separator is a most important element, as the exhaust steam, after being purified through the separator, is brought into direct contact with the boiler feed water, raising its temperature to almost the boiling point.

It may be of interest to note that these Cochrane feed water heaters are growing steadily in favor among steam engineers, and are being used by the General Electric Co. in connection with steam turbines at their plants at Lynn, Mass., and Harrison. N. J., also at other large electric power plants of 1,000, 2,000 and 3,000 H. P. capacity or larger. Three 5,000 H. P. Cochrane heaters have been installed at one plant for the Detroit Edison Co. To anyone interested in steam power plants, a careful consideration of the separators, their construction, operation and efficiency, should be of value.

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* "St. Louis Bridge," by Prof. C. M. Woodward, page 190.

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Regular Meeting—1st Wednesday evening of each month except January July and August.

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NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

PAPERS ON REINFORCED CONCRETE

The present and preceding numbers of the Journal contain several papers on the very live subject of "Reinforced Concrete." Copies of the Journal may be obtained on application to the Secretary. The price is 50 cents per copy or $1.00 for the two numbers containing these special papers.

Journal of the

Western Society of Engineers.

VOL. IX. OCTOBER, 1904. NO. 5.

FIREPROOF FLOOR CONSTRUCTION.

J. T. Montgomery, Jun. M. W. S. E.

Read Sept. 7, 1904.

I propose to confine my remarks this evening to one of the standard methods of protecting the structural steel in buildings against the injurious effects of fire; I refer to concrete construction, and I will try and explain briefly the application of this material, with some of its advantages and disadvantages.

Regarding the strength and durability of concrete floors, much has already been presented before this Society. I have myself been present at several meetings where the strength of concrete as common concrete and as reinforced concrete has been very thoroughly gone into, and the discussions were upon the different methods of best developing this strength, but there was no question but that it was a most satisfactory material where heavy loads were to be carried. So for our purpose we may consider this question established, that by proper designing, concrete can be constructed to meet every requirement of strength and durability.

But as to its fireproofing qualities, we find that they differ widely under different methods of construction, as may be properly said of any material. The requirements of an ideal fireproofing material for the protection of structural steel are:

First—That it shall not itself be affected by fire.

Second—That it shall protect the steel from the effect of fire and heat.

Third—That it shall protect the steel from the effect of corrosion.

Fourth—That it shall go into place rapidly and be easily adapted to unusual designs and details of construction.

Fifth—That once in place it shall resist to the greatest possible degree all effort to remove it, by either of the elements or by human agency.

Sixth—And last, but not of the least importance, in this age of commercialism, it shall do all of these and do them well at a reasonable cost.

First—That it shall not itself be affected by fire.

This certainly is the first consideration in the choice of a fireproofing material. At high temperature it must not lose its strength or become plastic, and it must be capable of quickly adjusting itself to meet sudden changes of temperature, such as, when a fire has been burning for some time, the sudden application of a stream of water from a fire hose; this sudden cooling and the change in dimensions due to it must not create a stress in the material which is sufficient to appreciably affect its strength. You can readily see that the more dense the material the less it is suited to meet this requirement.

Further, the several component parts which enter into the forming of a fireproofing material must have been manufactured at a reasonably high temperature or be of a refractory nature.

All concrete is a very poor conductor of heat, but the more porous its construction, the slower heat reaches its interior, and here we have two classes of concrete; first—stone or gravel concrete, and second—cinder or slag concrete. Of the two classes stone concrete is *less desirable* from a fireproofing point of view, although it possesses the *greater strength*, but if the application of heat is of sufficient duration, it will penetrate the concrete in spite of its poor conductivity, and affect the stone used in its construction, but this may be expected only in severe conflagrations. In Baltimore this effect was never observed to extend more than ¾-inch to 1-inch, and in many places did not appear at all. And the dense concrete made by the use of stone will not adjust itself to a sudden change of temperature as rapidly as cinder or slag concrete, which is much more porous.

In cinder concrete practically all of the materials have been subjected to very high temperature in the course of their manufacture, which is an advantage over concrete using stone. It has been demonstrated in the tests of this material, and by fire, that cinder concrete does not suffer from the effect of heat even when exposed to very high temperature for long periods of time.

I have examined cinder concrete which passed through the Baltimore fire, and it was not affected in the slightest by the heat. I do not refer to isolated instances, but to the general condition of the concrete where used for fireproof floors. I did, however, see considerable strip or sleeper filling which seemed to have no strength, but it never had been more than a cinder fill, the only use of cement in its connection being the mention made in the specifications and it is a matter of conjecture if it even appeared there.

I examined at one time a specimen of concrete which had passed through a five hour test made by the New York Building Department, where for more than three hours the temperature had exceeded 2,000 deg. Fahr. and this specimen was in A No. 1 condition; nails could be driven into it and be held as though they were driven into hard wood, and it is this quality which I refer to as toughness, in counter-distinction, to the quality of brittleness of the more dense material, as tile and stone or gravel concrete. This is to be considered of prime importance in the selection of a fireproofing material as sudden changes of temperature, such as are liable to come at the moment of supreme test, have no serious effect on a fireproofing material with this quality.

First National Bank Building, Cincinnati.
Ferro-Cinder-Concrete Floor Construction.

The second requisite of a fireproofing material is that it protects the steel from the effects of fire. To do this it must be a slow conductor of heat, assuming, of course, that the material remains in place. Here again the porous material has the advantage and cinder concrete excels stone concrete as porous tile is supposed to excel the dense or hard tile. Mr. Stevenson Constable of New York, who has made extensive tests in this field, reports that it required 3 hours and 54 minutes for a *temperature* averaging between 1,900 and 2,000 to make its appearance through 5 inches of cinder concrete so as to be detected by the touch of the hand, and 4 hours and 24 minutes were required before it became too warm to hold your hand on, which demonstrates that as a non-conductor, cinder concrete leaves nothing to be desired and steel protected by it is reasonably safe from the effects of fire.

Next—The protection from corrosion.

It has been thoroughly demonstrated and generally accepted for some time that there is no building material superior to Portland cement for the protection of steel from this danger; it then only remains to make sure that no material is introduced into the concrete which will result in a detrimental effect.

When stone or gravel are used in concrete there can be no question raised as to its safety, but where cinders are used it becomes necessary to assure ourselves that we are still safe; as cinders are known to possess a small percentage of sulphides in the forms of the anhyride of sulphuric acid, which is very quick in causing corrosion. Iron pipes embedded in cinders where water was present have been practically destroyed in a few years. But to determine to what extent this material became a danger when mixed with Portland cement which has an alkaline reaction, many tests have been made by eminent chemists and engineers. Messrs. Booth, Garrett & Blair, at their testing laboratory in Philadelphia made a very exhaustive series of investigations, which resulted in their determining that the objectionable sulphides amounted to four-tenths of one per cent in pulverized cinders and in the coarse cinders, as used in actual practice, the avaliable sulphides are much less than this amount and *not* as much as could be neutralized by the alkaline reaction of the cement. In the conclusion of their report they state:

"The conclusion that we reach is that no injurious effects are to be anticipated from the use of cinders above ground in the ordinary practice of construction now followed for steel frame buildings.

(Signed) "BOOTH, GARRETT & BLAIR."

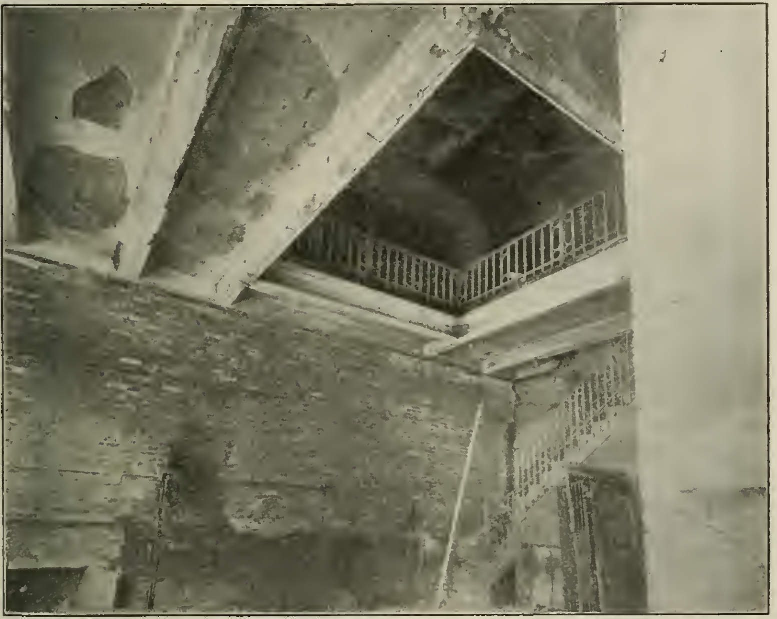
Again we find by examining the report published in the *Engineering News*, made by Prof. Charles L. Norton of the Massachusetts Institute of Technology for the Insurance Engineering Experiment Station. He states in conclusion:

"Mix wet and mix well; with this precaution I would trust cinder concrete quite as quickly as stone concrete in the matter of corrosion."

His purpose in mixing wet is to secure a complete covering of the steel, as void or unprotected parts permit corrosion from the presence of moist air.

It has also been found where buildings have been taken down several years after erection that, where cinder concrete was used as a fireproofing material, the steel was in good condition. An instance of this was the Pabst Building at Broadway and 42d street, New York, which was razed last year, and was watched very closely by architects and engineers for the data it might afford on this subject.

It was erected in 1899, cinder concrete being used for the fireproofing of the floors and tile for the columns. The building had been in place for four years and its condition may be taken as a fair example of what may be expected. The floor steel was practically free from any corrosion. "The Insurance Engineering" in its report sums up the conditions as follows: "The steel frame generally was remarkably clean and free from rust. The conclusion to be derived is in ample corroboration of what engineers have been fully convinced of—that concrete is a very efficient protection to steel against rust and that well made cinder concrete serves this purpose very satisfactorily." So it seems from quite an ample investigation that we are safe in our protection against corrosion when we use cinder concrete.



National Bank of Commerce in Baltimore, after the fire.
Ferro-Cinder-Concrete Construction.

The fourth of our requisites has to do with the practical application of the material used for fireproofing.

A material may be ideal in those considerations already mentioned but unless it will go into place rapidly and stand any and all kinds of rough handling, it cannot come into general use, and at the same time it must adapt itself to unusual details and odd corners and must be so as to be fitted to these conditions at the building, as an ⅛ or ¼-inch scale drawing cannot be used at a factory in getting out special shape for places which require an inspection of the steel construction in place to determine what is required. We often see jobs of fireproofing which have a decidedly patched appearance because the material could not properly be fitted to the conditions as found at the building.

Concrete being put in place in a plastic form can be made to fit all conditions on practically a moment's notice and leave a finished appearance.

The materials used are simply cement, sand and stone or cinders; they occupy a small space and come to the building in convenient size. It is well known that space is at a premium around a new building which is being put up in record time. The materials used in concrete on arrival at the building site are at once sent to the basement where they are stored and mixed and prepared to be hoisted into place.

The machinery now used in the handling of concrete makes it possible to place large quantities of floor construction in a limited time, and it is only a question of securing a contractor for the fireproofing who has the necessary equipment and practical knowledge to insure yourself that the job will go forward as rapidly as the steel will permit.

Concrete construction as a general proposition has suffered from having too many inexperienced and financially irresponsible firms engaged in the business. Architects, engineers and owners have permitted themselves to be persuaded into accepting a low bid made by parties who are not competent to do the work. If trouble results, as is likely, the system of construction is liable to receive a large part of the blame as the architect or engineer is not going to reason that he tried to get something for less than it was worth and was entitled to be bunkoed.

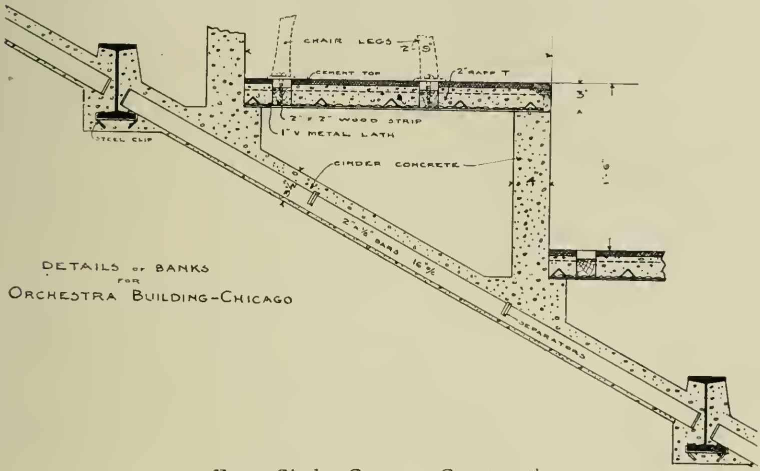
So not a small share of our fourth requisite is the man behind the gun, or the man who manages the business, and here experience and a thorough knowledge of the construction are absolutely necessary for successful results.

Fifth.—That once in place the fireproof floor construction will remain under any and all conditions. This point was partly covered in our first consideration, which provided for a material which was not affected by fire.

The material which will take sudden changes of temperature without cracking or disintegration, that also has that toughness which will permit the rough use incident to years of service without being loosened, is the material which must eventually command first consideration, and for these qualities concrete stands without a peer, as capable of taking more punishment without leaving its post of duty than any other practical construction now in use.

And last, it shall do all these and do them well at a reasonable cost.

There are two distinct elements of cost—first, the cost of the material; second, the cost of the labor required for its installation. The cost of cement, as you well know, is very reasonable, and with the inexhaustible supply of raw material and the improved methods of manufacture it is not reasonable to expect any decided change. Sand and stone are staple and can always be had at a uniform and reasonable price. Cinders are very cheap and the supply is constantly on the increase.



Ferro-Cinder-Concrete Construction.

The second item of expense is the labor, and here the conditions are never so satisfactory. You are all too familiar with the strikes and disputes which are constantly disturbing this market for me to review so unpleasant a subject. But by the use of concrete this part of the cost can be much better controlled than where a more skilled form of labor is required, and with the machinery continually being improved for the mixing and handling of concrete the cost of labor can be constantly reduced and better controlled.

The company I represent has but recently adopted a new machine for mixing concrete which, with the aid of six common laborers, mixed and delivered to the hoist 125 cubic yards of concrete in eight hours. This machine measured automatically all the material used in the concrete, insuring absolute uniformity of results and a low cost of production.

With this array of facts is it not reasonable to expect that concrete will, before long, universally enjoy that recognition that is already given it in so many of our principal localities—the first among fire proofing materials for floor construction and the protection of structural steel?

STANDARD FLOOR ARCH CONSTRUCTION.

E. V. JOHNSON.

Read September 7, 1904.

When an engineer has made his computations and prepared the details for the foundation of a building, it may be said that the most important part of his labor has been accomplished. Before, however, the structural details of the foundation can be definitely determined, it becomes necessary to carefully and accurately compute the weight units entering into the superstructure.

In no other city, perhaps, in America, has the question of foundation received so much careful consideration from engineers as right here in Chicago, on account of the nature of the sub-strata underlying the surface, upon which the weight of the structure must be proportionately distributed.

The necessity for a system of floor construction that was light and strong arose just about the time that the high building era set in, and the hollow tile method was adopted as soon as presented, in order to reduce as much as possible the superimposed load on the foundations of walls and columns.

About twenty-four years ago, the Montauk Block was erected on Monroe street, from plans prepared by D. H. Burnham & Company, architects of this city.

The foundations of this structure were rubble stone; the exterior walls of the building solid masonry, of varying thicknesses, as called for by the building ordinances then in force.

This building was nine stories in height, and was considered at the time a "skyscraper." Within a very recent period, this structure has been razed to make place for an eighteen-story modern steel skyscraper for the First National Bank.

When the plans were drawn for the Montauk Block, a great many different systems of fireproof floor construction were considered, to-wit: Brick arches, corrugated iron arches, filled in with concrete; solid concrete arches; Lime of Teil blocks and hollow tile arches.

As this was the first nine-story structure ever built, and higher than any other business building in Chicago, the merits and demerits of the different systems were carefully considered, and hollow tile arches were accepted for the floors of this building, for the reason that by the use of tile arches, the required vertical and horizontal strength was secured at a minimum dead weight of floor construction.

The tile arches in this building were what is known as side "construction" arches; the soffits of the beams being covered with 1-inch slabs of fire clay tile.

The spans between the beams, as I remember them, were about 5 feet, 6 inches. The beams were about 9 inches in depth, framed into girders, supported at intervals on cast iron columns.

I refer to this building particularly as I believe this was the first high building that proved a financial success to its owners, thereby stimulating the erection of similar structures, which has culminated in the present up-to-date thirty-story steel skyscraper.

The standard of construction adopted in the Montauk Building, for floors, is practically the standard of floor construction now in most general use for the erection of fireproof buildings.

There have been most important improvements, both in the form and the method of laying the arches, and also in the methods of designing and assembling the steel parts; but, to all intents and purposes, this general system of floor construction is to-day in force and effect, and is accepted by architects and engineers as "The Standard."

There are in use at this date, throughout the United States, in various buildings, embracing every description, from private dwellings to wholesale warehouses, over 200,000,000 square feet of standard tile constructed floor, equivalent to an area of almost 5,000 acres of floor surface.

Many buildings throughout the United States have been tested by fire to a greater or less degree, but the records of the insurance department show that the losses were merely nominal in all cases where the fire resulted from the inflammable contents of the buildings.

You are familiar with the Baltimore fire of February last. I refer to this subject that you may know that the standard system of tile and steel construction received a baptism of fire in this conflagration such as no other system of fireproof construction was ever called upon to sustain, *and did it successfully.*

The insurance reports state that the greatest injury to steel work in buildings fireproofed by hollow tile did not exceed 5 per cent, and this in only one case; the majority of the protected steel structures escaping with injuries of less than 1 per cent.

With a record, therefore, of over 30 years of general use, the standard steel and tile floor construction stands to-day unsurpassed by any other method.

There are numerous systems of floor construction that have been constantly exploited before the architectural and engineering professions during the past 15 years. Some of these systems have superior merit, compared one with the other, but there are a number of crude methods of floor construction, being advocated, that should never be allowed in a building.

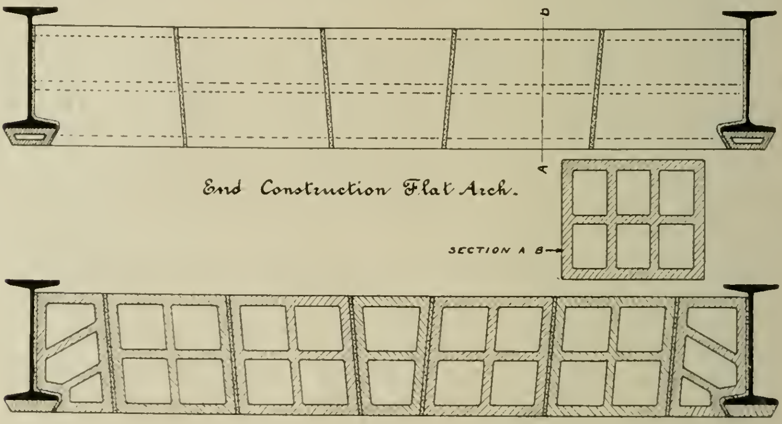
I justify this statement by the number of building accidents and collapses which have occurred during the past two years, aggregating in all, to my knowledge, 18 different disasters, several of them attended with great loss of life, all attributable to bad floor construction.

I am satisfied that if these constructions had been properly supervised by a competent engineer, and sufficient and suitable material used, and care taken in the proper installation of the same, the accidents would have been avoided.

The standard steel and tile construction has been before the public so long, that complete detailed specifications are now prepared by architects and engineers, specifying just what material is required; just how it is to be set in place; just what proportion of cement is to be used; how and when the centers are to be "struck;" and, in fact, careful and specific directions given, so that the hazard of constructing the work is reduced to the minimum.

This condition does not exist with the so-called patented systems of construction.

I was only recently called upon to furnish a fireproof estimate for a large hotel building. The architects' drawings showed merely the centers and location of the columns, the dimensions of the walls, heights of stories, etc. The fireproofing contractor was requested to submit a system of fireproof construction, prepare his own details of steel, also his own specifications, and give a written guarantee of the strength of the floors.



End Construction Flat Arch.

Side Construction Flat Arch.

Standard Hollow-tile Floor Coustruction.

The only responsibility the architects assumed was to dictate the live load per square foot that each of the different floors and roof were to safely(?) support.

The factors of safety, however, were not stated; hence, parties figuring on patented systems of construction might use a factor of two, or a factor of four, or a factor of six, both in the floor construction and also the steel work.

It seems to me that "wide-open" specifications of this character, which permit the most important part of a structure above the foundation, to be designed by men commercially interested in selling their products, is a very dangerous one for the public, who are called upon to occupy said buildings, and I believe it accounts for the great number of disastrous building collapses, through the falling of fireproof floors, which have occurred in recent years.

Again, in writing specifications of this character, legitimate competition is not obtained, because no two fireproofing concerns figure on the same plan of steel work and the owner would have great difficulty in determining (as between two different constructions) which one was giving him the most for his money, especially when you take into account the "insurance agent" *tactics* used by some of these patent systems to force their goods upon the public from a commercial standpoint.

An owner of sufficient intelligence to amass money enough to build a fireproof building would hardly be expected to consult his dentist on a question of law. The same owner, however, in many cases, to my knowledge, has gone to parties engaged in manufacturing cement and selling wire and asked them to design a steel skeleton floor and roof construction. I think you gentlemen will understand the point I am trying to make, which is, that there is no part of a building construction, above the foundation line, more important than the interior steel construction, and there is no part of a building that should receive so much care from competent engineering talent in order to insure the lives of the tenants and to assure the owners a safe and permanent structure.

Through the efforts and skill of the engineers of Chicago the steel skeleton frame construction has reached its highest type in this city, and has been emulated all through the United States and Canada.

This high standard of steel construction, incorporating, as it does, steel columns, girders and beams, thoroughly riveted together, is, in my opinion, the best and safest method of building fireproof structures.

I would space the beams between the girders the proper distance apart to give the maximum of strength with the minimum amount of material. These beams should be thoroughly riveted to the girders. Between these beams, build standard end constructed tile arches, laid in the best quality of Portland cement mortar; cover the soffits of all "I" beams with at least one and one-half inches of porous terra cotta tile, properly secured in place; and protect the sides and soffits of all steel girders with at least two inches of porous terra cotta fireproofing material.

When applying the fireproof material to all steel work, be sure to see that there is a full Portland cement mortar joint, covering all of the exposed steel, so that danger of deterioration in the steel, in later years, may be avoided.

In a general way, I have spoken of the standard floor arch construction. You are all more or less familiar with the numerous designs in use, including the flat arch, segmental arch, Guastivino arch, and numerous others, all more or less meritorious. I will not, therefore, go into details. It will however, be consistent for me to call your attention to one great advantage that the hollow tile floor arch has over any other system, especially in use in high buildings, and that is—that without materially increasing the weight of the floor, the fireproof arch blocks can be made the full depth of the steel beams, between which they are placed, thus stiffening the steel work horizontally and insuring economy in the quantity of steel required to resist the stresses of wind pressure.

Are there any disadvantages in the use of the standard steel and tile construction, as compared with any other systems on the market?

I claim there are none, unless, perhaps, there is a merit in the claim of a certain contractor, who said to me, "Johnson, you will soon be driven out of business by these concrete fellows. They can dump their sand and cinders in the cellar, while you have to use up the first floor to pile your tile on."

Of course, we require a certain amount of space at the building in order to incorporate our work properly, but I told my critical friend that while it was true we required space to pile our material, we did not occupy it very long, because, if given an opportunity, it would be possible to finish the floors of a twelve-story building, in place complete, within 12 working days, as was done in the Schlesinger & Mayer building, corner of Madison and State streets, this city, and you all know that there is no other system of floor construction that could be erected in the building in double this length of time.

Now, as to the advantages of the standard steel and tile construction:

First of all, when an architect specifies the hollow tile system of construction he sees to it that a proper steel skeleton construction is designed. If he has no designing engineer of his own he employs some engineer of reputation and ability to prepare his diagrams and details. This insures the fundamental character of the construction. The engineer knows the character of the material he is employing. There is no experimental stage to go through; no guessing as to strains; no uncertainty as to whether the mortar will "set" or not. It is all clear sailing to the engineer, and when his plans are prepared and competitive prices are asked, the owner is afforded legitimate competition, because his engineer tells him what he should use in the way of steel work and how he should use it, and all bidders are perforce required to figure upon the same basis.

Continuing on the merits of standard steel and tile arch floor construction, rapidity and safety of erection being granted, as exemplified by records made in the city of Chicago, I would refer also to the immunity this system has to the extremes of temperature; *rain, frost and snow* do not impede the installation of this work.

I have seen floor arches in the Merchants' Loan & Trust Building which were laid while the thermometer was twenty degrees below zero, thawed out with salamanders and plastered within forty-eight hours thereafter, the work being left in first-class condition.

To the capitalist, who has money invested in high-priced property, it would seem to me a great advantage that the work should continue regardless of weather conditions, thus saving delay and consequent loss of interest on investment.

In designing the steel work for the floor of a building, the most important consideration (outside of the steel construction itself) is the weight of the material used to build the floor between the beams.

There is no system of construction at present known to the building arts which can be built in place between beams, *the full depth of the beam*, that weighs as light as the hollow tile system.

There are numerous concrete systems for floors, in which the upper member is formed with a slab of re-enforced concrete, supported upon concrete raised up from the lower flanges of the beam; light suspended ceilings of wire mesh or expanded metal are then hung on the under side of the beams and plastered in order to form a straight ceiling below.

This form of floor will average from thirty-six to fifty pounds per square foot if built between 12-inch beams. The upper slab of concrete is usually built three or four inches thick, and while it answers to a certain extent as a horizontal re-enforcement to the sides of the beams, it does not fulfill the requirements of a stiff horizontal floor, the same as does the hollow tile arch, made the full depth of the beam.

A square foot of 12-inch porous hollow tile arches can be made to weigh not to exceed 30 pounds per square foot.

It will therefore appear that the hollow porous arch, if set between 12-inch "I" beams, can be built its full depth, and not weigh as much, within 20 per cent per square foot, as the concrete floors above referred to.

The above proportion of weight per square foot of floor will hold good on all beams varying in depth from 9 to 15 inches.

Beams of greater depth than 15 inches should be filled with 10-

inch tile arches, supported on raised abutments from the lower flange of beam, and light suspended ceiling tile should be built underneath the arches when straight ceilings are required.

As a matter of fact, however, it has not been found advisable, from an engineering standpoint, to construct floors with beams greater in depth than 15 inches, for the reason that the cost is too great.

Standard tile arches, as manufactured by us to-day, are made with at least one, and, in many cases, two horizontal interior webs. This adds greatly to the comprehensive strength of the tile; also serves as a non-conductor of fire from story to story of the building, and also as an excellent non-conductor of sound.

This is a great advantage in apartment buildings, dwellings, offices, hospitals, and any structure wherein the transmission of sound from floor to floor should be obviated.

Exhaustive experiments made a few years ago by Architect Dwight H. Perkins demonstrated conclusively that two thicknesses of hollow tile, with double air spaces, was a much better non-conductor of sound than any form of metal lath, double or single, or expanded metal partitions, solid or hollow, that could be found. These experiments were conducted at the time Mr. Perkins was determining upon the best partitions to use in Steinway Music Hall to divide the class rooms.

At the great fire in Baltimore, there were a number of cases where the soffits of some of the tile arches in the building were cracked and dropped off. The advocates of competitive systems have criticised standard steel and tile, claiming the fact that the bottoms dropped off as an evidence that the construction was not good.

It will appear, however, from tests which were made on all those arches left remaining in the building that the carrying strength of the floors was totally uninjured, notwithstanding some of the soffits had dropped off.

Messrs. W. A. and A. E. Wells, contractors of Chicago, conducted a series of tests, under the auspices of the Building Department of Baltimore, and certified that none of the arches would have to be removed from the building.

In fact, all repairs on these arches have been made by covering the holes left by the broken soffits with wire cloth, upon which plastering was applied direct.

The cost of making these repairs has been comparatively slight, in contra-distinction to the disaster which overtook the two upper concrete floors of the Fidelity and Casualty Building, in Baltimore, which were so badly wrecked that the entire structure had to be razed.

I have before referred to the rapidity with which tile arches can be installed in place in the building, and also the fact that the work can be carried on during any portion of the year regardless of weather conditions.

The same quality which makes it possible to erect hollow tile under these adverse conditions also insures the rapid drying out of the floors after erection. The moisture in the plastering underneath and the concrete filling on top of the arches is absorbed and carried off through the hollow spaces of the floor, thus eliminating the large quantity of moisture inseparable from any and all systems of concrete construction.

It is not an uncommon thing for concrete work to remain damp and require anywhere from four to eight months to become perfectly dried out, depending entirely upon the the thickness of the slab and the weather conditions at time of installation.

The injury to hard wood floors, interior finish, cabinet work, furniture, etc., on account of the damp conditions incident to buildings of other than hollow tile, gives evidence of the great advantage of this material as compared with all others, especially in cases where the work must be carried on rapidly and continuously from start to finish.

The standard floor arch construction, upon which I have dwelt particularly, is familiar to all engineers, and I believe, as compared with any other system of construction, has held its own against the inroads of competition fully as well as any other system of building construction before the engineering world.

There is yet much improvement to be made in the manufacture and application of the hollow tile system.

It can be greatly improved by increasing the thickness of the material; careful inspection; and the selection only of the best qualities of clay.

Owing however, to the fact that this is an age of strenuous competition, the manufacturers and contractors for hollow tile fireproofing, have been obliged to sell only such material and methods as the public were willing to pay for.

It is to be hoped that the young engineers, who are graduating every year from your various schools of technology, will take hold of the subject earnestly and endeavor to improve the systems of construction as they stand to-day.

I claim for the standard floor arch construction that there is nothing uncertain in its component parts.

The material can be tested in units or as a whole.

The workmanship of installation affords small chance for disaster or collapse.

The possibilities of improving the combination of structural steel and hollow tile for floor construction are as great to-day as they ever were, and it is to the engineers of the future to whom we look for these improvements.

The various monolithic systems of concrete at present on the market appeal to the young engineer, for there are certain elements in armored concrete that are alluring to the technical student.

Let it be borne in mind, however, that the standard floor arch construction of to-day is far from perfect, but let there be an effort made to better a system which has withstood all competition for the past 30 years, and bids fair to hold its own for many years to come.

DISCUSSION.

Mr. Hagn (German Engineer)—At the request of the Secretary of your Society, I take pleasure in saying a few words on this subject, although I shall have some difficulty in expressing myself in English on account of not being very familiar with the language.

Referring first to the paper by Mr. Montgomery. He states that concrete floors will not be affected by fire. In connection with fireproof construction we have to consider not only fire, but also the water used on the fire. We have protected columns with concrete from 3 to 3½ inches thick, but this was injured by water from the fire engine. Fireproof construction must not only stand against fire, but it must be able to carry the load which comes on it, and concrete without iron in it will hardly be able to carry a load for a longer span than 8 or 10 feet. At the present time in Germany, floors are constructed of brick with spans up to 24 feet.

We do not use cinder concrete in the construction of buildings, because we believe that iron will be corroded by it. Our concrete is mixed by machines, but we do not use a very strong mixture; this is composed of 1 part cement, 8 parts sand and 12 parts gravel.

In fireproof construction in Germany the stairs are always made entirely of concrete; no iron beams are used in the staircases, and they are generally surrounded by brick walls. These concrete stairs are made beforehand with some rods in them, and are put into the masonry so that they carry themselves with a free end—a cantilever.

In our floors, the main thing is to calculate the iron to be used. It has always been our custom, in using iron in concrete, to follow an elastic line.

We consider a girder fireproof, when the compressive part is protected. We are not so anxious to protect the tension part of the girder, but the insurance companies require it; the engineers, however, do not consider it necessary. Recently we have built the floors with brick, and build spans to about 22 feet. Some engineers build floors with hollow bricks. Our hollow bricks have just a small opening in them not larger than one inch in diameter, and these brick floors are heavy—more so than floors built with hollow tile.

I do not think that the protection of the lower part of the girder as shown in one of the illustrations would stand against a heavy fire up to 1,200 degrees, as I think the concrete would all fall off.

We are not so anxious about the floors; our main consideration is to protect the columns against fire, and the stability of the building depends on the columns and not on the floors. It does not much matter if one floor does break down.

Mr. Johnson stated that in this country some architects show only the centres of the columns on the drawings. We have to draw and calculate every girder and every column, and have to show this in special plans before calculation for the cost is made.

The cement and concrete floors in our country carry the sounds from one story to the next higher, and to lessen this sound, cinder concrete is put about the floor, with very little cement—1 to 20; we make the floor of concrete, and above that place 2 to 3 inches of cinder concrete and over this 1 inch of cement mortar—1 part cement and 1 part sand. In Germany we do not put any wood on the floors. We have the cement floors but sometimes we put on some linoleum.

We do not put any iron into the outside walls of a building, as we make the masonry carry the load; we say, the more iron in the building the more danger from fire, and so we keep the iron out where we can. Neither do we put any iron in the arches over the windows.

Mr. Johnson—Would you not do so if you were erecting a building 16 or 18 stories high?

Mr. Hagn—No, I would not.

Mr. Johnson—You would have to use steel if you finished the upper stories first, as we often do here.

Mr. Hagn—No, I do not think we would. On the outside of the wall there are some wooden columns to carry the girders which rest on the masonry. We do not construct the iron as you do, as we try to bring the load of the girders centrally upon the column; we never have it on one side of the column. We consider this eccentric loading a fault, and generally we do not join the girders on the column, but we make the joint a cantilever; so we always get a central load on the column. We seldom fill up the columns; we protect the columns outside, but not inside. I understand you fill the hole inside the columns with concrete.

Mr. Condron—I would like to ask Mr. Hagn if in Germany they have any seventeen story buildings with masonry walls running down to the ground?

Mr. Hagn—No; we do not have such high buildings. Any protection of our columns against fire is generally made of limestone concrete. We do not consider it fireproof if not protected again with some sheet iron outside. We very seldom protect our columns with bricks; generally with limestone concrete or with Monier concrete, and this is again protected by sheet iron.

Mr. Warder Does that iron go all the way to the ceiling, or only part way?

Mr. Hagn Some make it up to the ceiling; others put it up only about 6 or 7 feet from the floor.

We have found that the fire streams will injure the columns but not so much so, but that they can be used again in the reconstruction of the building. The columns are generally made of cast iron, as we think that cast iron will stand more than wrought iron. We do not protect the roofs at all. They are generally built of wood.

Mr. J. L. Mensch—In regard to Mr. Johnson's remark that steel skeleton and hollow tile are the only fireproof construction, I wish to say that I remember several fires where it did not seem that hollow tile did so very well. I understand that in the Horne fire in Pittsburg, more than 25 per cent of the fireproofing had to be replaced; while a concrete floor of 16-foot span, in a building right across the street, in which all the interior burned out, stood all right.

We can have reinforced concrete construction sometimes at less cost than slow burning wood construction. I am, at present, erecting a ten story building of reinforced concrete for less money than a slow burning wood construction would cost.

How can he recommend steel and hollow tile as the only construction, when he can get a perfectly safe fireproof building for considerably less money?

Mr. G. J. S. Collins—I would like to ask Mr. Johnson if he included his long span system amongst those which he condemned in his remarks.

Mr. Johnson—Yes I do. I am on record as being averse to long span construction referring to monolithic methods, in which steel rods or bars are embedded in cement, and the floor subjected to extreme transverse strains.

Mr. Blumenthal—In regard to the cinder concrete construction, I have in mind a case where this was used in connection with a boiler foundation, and sometime afterward this was taken out—one glowing mass of coal.

Mr. B. J. Ashley—I was very much interested in an article written by Prof. C. L. Norton of the Massachusetts Institute of Technology, in which he states the fact that, after subjecting the concrete to a heat of about 1,000 degs. Fahr., a surface disintegration of the concrete took place through dehydration to a depth of about ¼ inch; beyond that the concrete was not destroyed. In the repaired buildings the cost of the repairs would be quite a minimum, under such circumstances. Now, it is clear that the heat would have to be greatly intensified to dehydrate the cement for another ¼ inch, with this insulated coating on the outside, and it occurred to me that this statement, being correct, that concrete is a good fireproof material.

Referring to the strength of hollow tile floors, there occurs to my mind a little incident that happened at the Owings building a number of years ago, when during its construction a safe fell, destroying a portion of every floor from the top to the basement, and I would like to ask Mr. Johnson if the hollow tile construction of floors was installed in that building?

Mr. Johnson—You are right about that accident; but instead of its being a safe it was a water tank.

Mr. Ashley—It occurs to me that with the proper construction of reinforced concrete, such an accident could not have taken place under similar circumstances.

Mr. E. N. Layfield—I would like to ask Mr. Montgomery whether those arches shown in the illustrations were of cinder or stone concrete.

Mr. W. L. Abbott—I think it is pretty well established that cement is a great protection to wrought iron beams, about which there was great anxiety at the beginning of the present style of steel construction. A short time ago I had occasion to investigate the condition of the girders in a vault supporting a railroad track in a power-house, the vault being continually moist from steam. The bottom of the girders not being protected, and always being damp, accumulated a very thick coating of scale. After the installation had been in for a few years there was considerable uneasiness as to the possible deterioration of the remainder of the beam, and it was thought it would last only a few years if it was rusting like the exposed flange. Accordingly, I had the cement chipped away to expose the web of the beam, and found it to be perfectly clean. Of course the cement adhered to it, but there was no indication of rust. I concluded that the best protection for the bottom of the girder would be to sling a trough below the girders after cleaning them off, and then fill this up with concrete, completely encasing the iron. I presume that protection will stand for all time.

Mr. Johnson—The Owings building was constructed about 18 years ago, and the company I was with at that time had nothing to do with the work. The floors were put in place by the Chicago Fire Proof Co. The tiles used were extremely thin shells—something like ⅜ of an inch—and were built on the side construction principle. There was a large water tank on top of the building, and in some way or other, in adjusting it, the derrick slipped and the tank broke through to the basement and carried the arches and steel beams with it. But the tile construction companies do not now use the side construction arch; they use the end construction;

and we have numerous evidence of falling weights on our construction that stopped right on the floor below.

In Baltimore, in the Continental Trust Building, there was a very large safe on one of the floors, set up on wooden blocks, and weighing about three tons. The fire burned the wooden blocks from underneath the safe and it fell over, but stopped right on that floor and very slightly damaged the arches.

As for impact, under ordinary conditions, the tile system will stand all requirements. The fact that there are so many million feet in place and under so many different conditions, should leave no room for criticism of the strength of the construction at this late date.

Mr. Mensch has given me some light on the subject of concrete and I want to congratulate him. He says he can construct a building of concrete cheaper than wood. Well, I hope he can, because I am averse to wood construction; I have fought it all my life and the more concrete buildings that are put up, the better it is for the fireproofing business, because it means so much less wood used. I am not going to criticise what Mr. Mensch has said about the cost, but if he can put up a concrete structure cheaper than wood, that will stand up to building requirements, he will do better than any other engineer has done in this country to my knowledge.

As to the fireproofing qualities of cinder concrete, I listened to the very able paper of my friend Montgomery, and I want to congratulate him; it was a very excellent paper. The statements, however, will not, in my mind, hold water, and I know his fireproofing will not stand it. In the Baltimore fire, the severe tests were in the upper stories. There were no concrete buildings higher than the Fidelity Building—the two upper stories of this building got a pretty good roasting by fire. The result was, when they tested the floor it was found to be very weak. I noticed a test was made by Testing Engineer Johnson, of the Johns Hopkins University. He took samples of the floors of that building to his laboratory, and it was found that while from the lower floors, where there had been no fire, it was good under compression up to 350 pounds per square inch, yet the material taken from the two upper floors, where the fire had been most severe, did not show a compressive strength exceeding from 9 to 30 pounds per square inch. Any material that will deteriorate under one heating from 350 pounds to the inch to 9 pounds, is not very good. Take that same material and use it in columns, what is going to be the result in case of severe fire? Your material is destroyed.

Mr. Blumenthal's remarks reminded me of an incident in connection with the use of cinder concrete. The case was in connection with some core ovens where the heat was not over 900 degrees. The foundation was put in, using cinder concrete, and the foreman reported that there was something the matter with the core ovens—that they were sinking. He stated that he had some expensive cores in the ovens and did not want to lose them. On examination it was found that the heat from the core ovens had set the cinders on fire, and the foundations were completely destroyed, and the whole thing had to be taken out. Fireproofing that burns is not fireproofing. It is a good deal like this so-called fireproof wood that the U. S. Government has awakened to the fact is not fireproof, because it will burn. I have made tests of cinder concrete and stone concrete and none of the cinder concrete and stone concrete I have been able to make will stand fire and water separately, or fire and water combined, without practically destroying it with one heating. In regard to the concrete that our friend Montgomery speaks of, I would like to get the formula of how to make it so it will stand fire.

I have a little yard out on the South Side that I would be very glad to have a committee of this society visit and make some experiments. I think I could demonstrate, to any man's satisfaction, that concrete is not fireproof, and you can test it yourselves. You need not go through an elaborate series of tests to find this out, either. Take an ordinary cement briquette and heat it to 1,200 degrees and let it cool gradually; you know what corresponding briquettes have stood in the testing machine before heating; now put one in your machine after heating, and you will find that it has deteriorated 50 per cent. If the cement briquettes deteriorate under heat, certainly fire injures the concrete. So much for concrete.

We all know what burnt clay is; we know that when we want to build a furnace we do not make the bricks to line that furnace of cinder concrete; nor do we, when we want to make cement, line the cement ovens with bricks made of Portland cement. You cannot find an engineer in the country that will do it, because he knows it will not stand. It is not a fire resisting material. What does he use? He uses fire clay for the purpose. That is the base of our material. I think we have the best thing on the market for the reason that it is fireproof material and has the basic qualities that will resist fire.

Mr. Abbott—I have tested a great deal of cinders, and find that cinders are cinders, whether they contain 1 per cent or 50 per cent of combustible material. Possibly Mr. Montgomery will tell us how much combustible would be permitted in his mixture.

Mr. Montgomery—We use principally, for fireproofing material, cinder concrete. We get the cinders from the large boiler plants you find all over the city now, and it is a poorly managed plant that permits much of its combustible coal to get through the fire box. You will find, with the mechanical stokers which they have today in nearly every plant, that the coal is completely consumed.

The result is the cinder concrete will probably take a higher temperature than the burnt clay products referred to by Mr. Johnson. We have had construction material come closely in connection with fire, and have never yet had any burst out in flame and burn up; if such a thing has occurred it was probably because the cinders were made in a cook stove at home, and were not the uniform product from large plants where most of the cinders are obtained.

In regard to dehydration of concrete, as referred to by Mr. Ashley. This matter was brought up in connection with the Baltimore fire by Mr. Sewell. It is a fact that at a temperature of probably not to exceed 1,000 degrees the water of crystallization in the concrete is liable to be driven off. This is immediately replaced by carbon dioxide, and the non-conductivity of the material is such that only by very severe and very long periods of heating can the material be affected more than ¼-inch to ½-inch in depth. The fact that the concrete he refers to went through this extremely high temperature in the conflagration speaks very well for the low thermal conductivity of the material. In other words, after going through this test it demonstrated that 2,400 degrees applied until all combustible material within reach was consumed, did not destroy the concrete. With material that has the non-conductivity that concrete has, it will take a great many fires to injure it to any considerable extent.

In answer to Mr. Layfield's question, I wish to say that all of the concrete arches shown in connection with the Baltimore fire were of cinder concrete.

The extreme test of any fireproofing material is water. Baltimore furnished us very little data in that respect, as practically little or no water was used during the fire because the temperature was such that the fire department could not get within fighting distance. Rochester, N. Y., is a good example. There was a large building there—the Granite Building—(ten or eleven stories) on fire, and the fire and the firemen had undisputed sway for some time. Most of the combustible material was consumed. The contractors for the reconstruction of that building found that 90 per cent of the tile arches had lost their soffits. The contract for reconstructing this building was awarded to a concrete concern, and the floor arches were tested, and where they developed the required strength they were left in place; the remainder of the tile was removed and concrete substituted. Where the tile arches were not removed a wire lath ceiling was constructed below them to conceal the damaged soffits of the tile.

As to the question whether or not concrete will stand high temperature, that matter was very thoroughly gone into, but it seems to have been overlooked by some parties. A few years ago a very warm debate took place in New York, and some elaborate tests were made. The result of these tests uniformly demonstrated that concrete would stand a high temperature, and for a long time. The New York fire department determined that five hours was about the limit of time that a fire could burn before being brought under control, so the tests were conducted on that basis. The temperature after thirty minutes would reach 1,200 to 1,500 degrees; it then immediately went up in the neighborhood of 2,000 degrees and for at least three hours the temperature maintained was about 2,000 degrees; 2,300 degrees is practically the limit of the temperature that can be reached by burning wood under a natural draft. All of the tests of concrete constructions went through in elegant shape. The tests were made on each construction independently. At the conclusion it was thought advisable to demonstrate the relative merits between hollow tile and concrete, and a vault was built 14 x 10 feet. The roof of that vault consisted of one tile arch and one concrete arch; the conditions were identical, and no exceptions taken. The New York Building Department was so careful that a watchman was kept on that building 24 hours a day, and every person that came within gunshot of that test was asked what he came for, and what he did was noted. They were tested until one or the other failed; the result was the tile arch failed while the concrete remained in place. It was the intention that if, after a reasonable time, neither failed, they were to be given an additional load. It was the intention to put water on the arches, but that was not done.

UTILIZATION OF EXHAUST STEAM IN CONNECTION WITH LOW PRESSURE STEAM TURBINES

By Mons. Leonce Battu

Read Sept. 21, 1904.

The vast strides that recent years have seen in steam engine practice, such as the use of high pressure steam, multiple expansion, superheating and condensation, have resulted in reducing the steam consumption to a point beyond which it is almost impossible to go.

But while these improvements have resulted in the attainment of high economy in many classes of steam engines, there is one great class in which the steam consumption per horse power is still extremely large. This class is composed of those engines whose daily service consists principally of starts and stops, such as rolling mill engines, winding engines, elevator engines, etc. The enormous quantity of steam which such engines exhaust into the atmosphere constitutes a loss, the extent of which can hardly be realized. Nor can the improvements that have been so beneficial in the case of continual running engines, produce like economies if applied to these intermittent running engines by reason of the adverse conditions under which they are usually operated.

Trials of modern winding engines frequently show a steam consumption of 65 to 80 pounds per horse power in mineral hoisted, while 100 to 120 pounds is not uncommon, so that allowing 20 per cent condensation in the cylinders and passages of the engine, there is discharged into the atmosphere by such an engine a minimum of 9,000 to 10,000 pounds of steam per hour which is totally lost.

This steam is theoretically capable of developing 500 to 600 horse power if supplied at atmospheric pressure and exhausted at a vacuum of 27 inches.

Rolling mill engines frequently consume 50,000 pounds of steam per hour, which is theoretically capable of developing over 2,500 horse power in expanding from atmospheric pressure to the vacuum of an ordinary condenser, even after deducting 20 per cent for condensation losses.

The consideration of this enormous waste of energy has caused many inventors to turn their attention to devising means for its reduction. As a result we have had proposals to utilize sulphur dioxide gas in an additional cylinder. While theoretically resulting in a saving, however, this system is fraught with so many serious practical difficulties that its use cannot become general.

By Rateau's system of directly utilizing the exhaust steam from intermittent running engines for power production, an enormous supplementary power becomes obtainable with but low first cost for installation. This system is entirely a practical commercial success, having been in operation for several years in Europe.

DESCRIPTION OF THE SYSTEM.

The principle of the process consists in the direct utilization of the steam exhausted from the main engines by means of low pressure steam turbines operated condensing and driving electric generators, centrifugal fans and pumps, blast furnace blowers, etc.,—in short, any apparatus requiring a constant rotary motion.

As the exhaust (usually at or near atmospheric pressure) from an intermittent running engine is unavoidably very irregular, and more or less discontinuous even, it is first of all necessary to regularize this discharge so that it can be delivered to the low pressure steam turbines continuously, and at a practically constant pressure. The apparatus for doing this Prof. Rateau calls a steam accummulator regenerator, or briefly, a steam accummulator.

THE STEAM ACCUMULATOR.

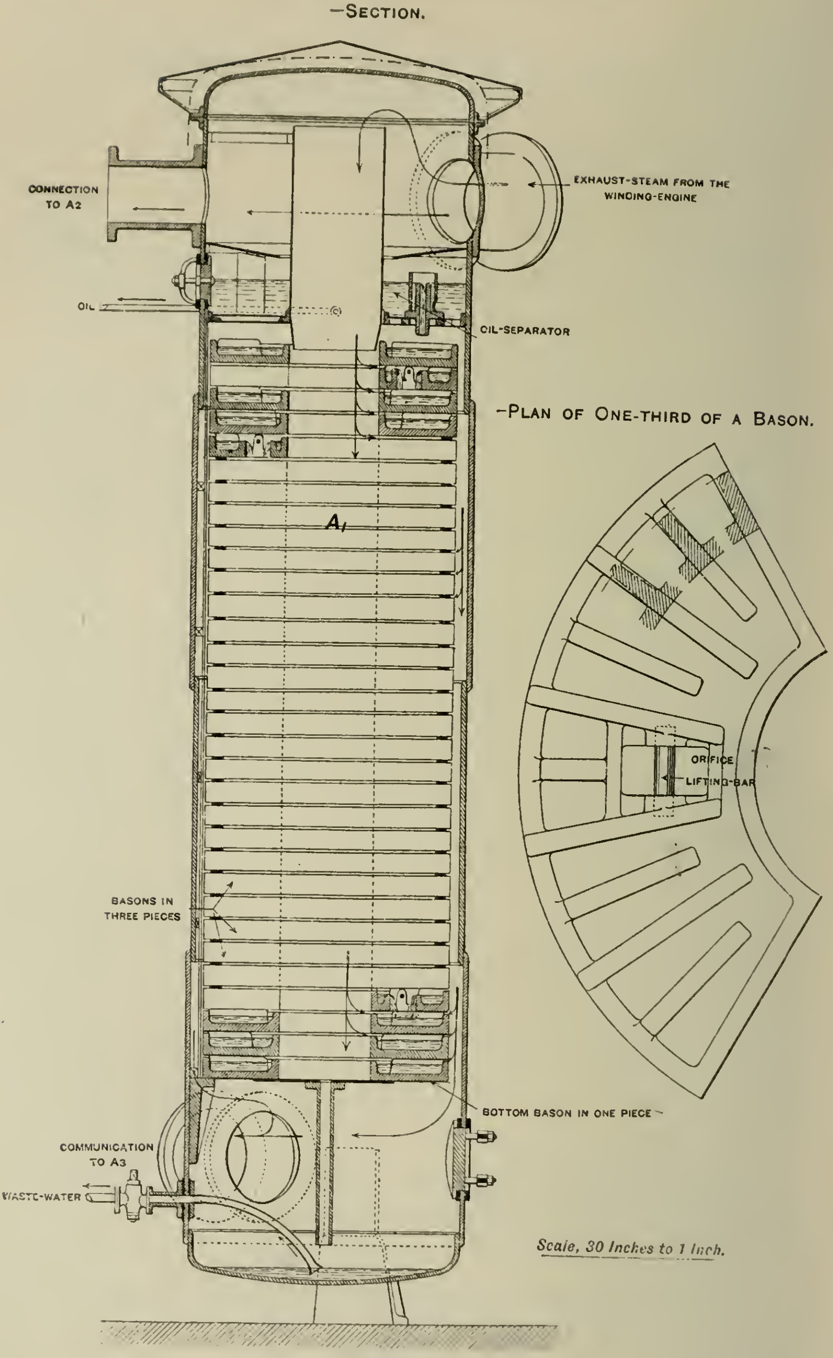
The steam accumulator is composed in principal of a vessel containing substances suitable for performing the function of a flywheel for the heat in the steam. On entering this apparatus the steam is condensed, at or near atmospheric pressure, and its heat so accumulated during the periods when the main engines are exhausting larger quantities of steam than are required by the turbine, with the result that the temperature and pressure in the vessel rise. When the supply of exhaust steam from the main engines falls off or ceases, the constant demand for steam by the turbine reduces the pressure in the apparatus, and re-evaporation or regeneration of the steam takes place with consequent reduction of temperature. The heat absorbed by the "heat fly-wheel" in the first period is given out again during the second period.

In practice, the variations of temperature are about 6 to 10 degrees F., which correspond to pressure variations of 2 to 3½ pounds per square inch.

The range of pressure is entirely controlled by the weight of materials forming the "heat fly-wheel" and by adjusting the safety valve of the apparatus.

The accumulator is built in four principal forms, depending on the materials forming the "heat fly-wheel":

1. Cast-iron pan type.
2. Scrap iron.
3. Automatic agitation of water.
4. Mechanical agitation of water.



—SECTION.

—PLAN OF ONE-THIRD OF A BASON.

Scale, 30 Inches to 1 Inch.

FIG. 1.

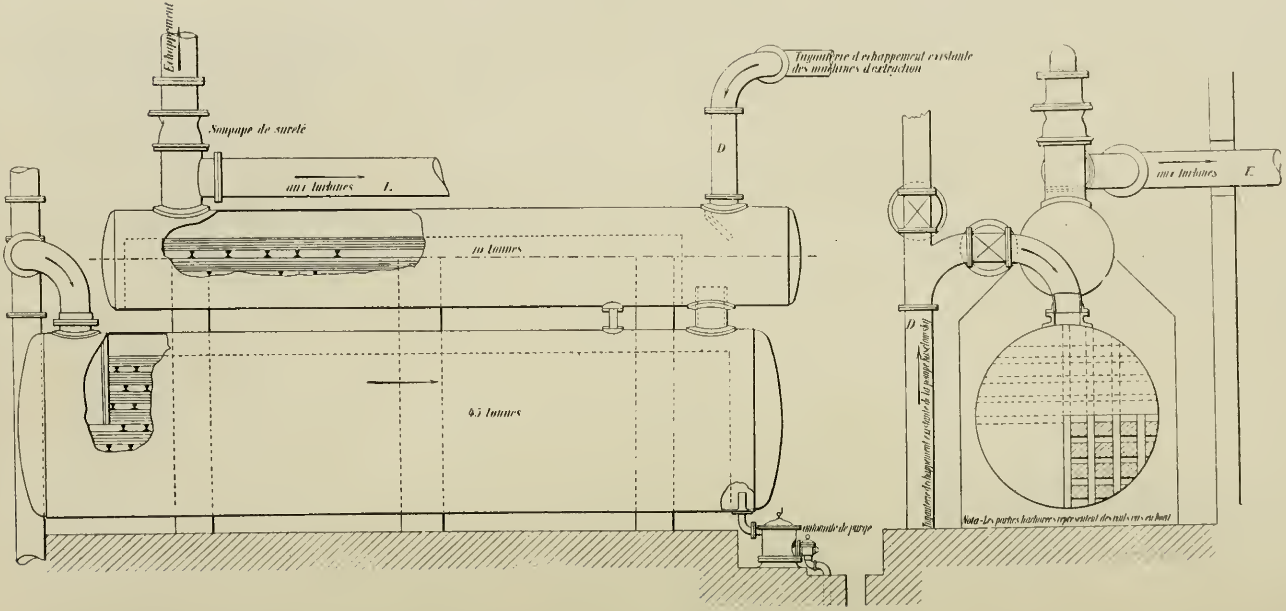

Echappement
Soupape de sureté
aux turbines
L
Tuyauterie d'échappement existante des machines d'extraction
D
10 tonnes
45 tonnes
automatique de purge
Tuyauterie d'échappement existante de la pompe Koselowsky
D
Nota - Les parties hachurées représentent des tubes vus en bout
aux turbines
L

FIG. 2.

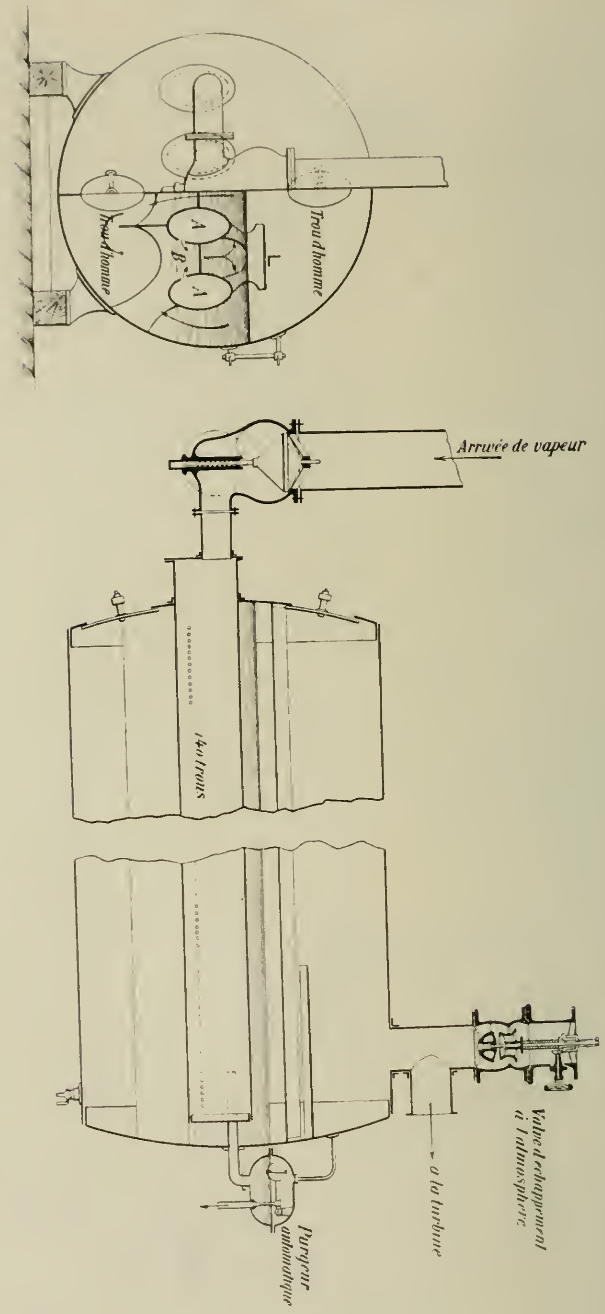

Trou d'homme
A
B
A
L
Trou d'homme
Arrivée de vapeur
140 trous
Valve d'échappement à l'atmosphère
à la turbine
Purgeur automatique

FIG. 3.

1. Cast-iron Pan Type.

An apparatus of this form is employed at the Bruay mines in France. It consists of one or more cast-iron tanks (Fig. 1) usually placed vertically and containing shallow pans of cast-iron. These pans are filled with water, when the apparatus is first put in operation, and the steam circulates between and around them.

The exhaust steam from the main engine enters by the upper pipe, as indicated (see Fig. 1), and passes to the pans by the central passage A. Part of the steam passes directly down the walls of the tank and the central passage, and flows to the turbine, or another accumulator, as indicated; the remainder of the steam is condensed, while the primary engine is exhausting, and is re-evaporated when the exhaust steam is cut off.

2. Scrap Iron.

A simpler arrangement consists of a tank containing old scrap iron. A 600 H. P. installation of this type is in operation in the Reunion mines of the railroad—"Saragossa Alicante Madrid," Spain. In this apparatus the cast iron pans are replaced by old rails. The tank can then be placed horizontally. In this type, however, the heat absorbing capacity of the water contained in the pans of the previous type is lost. However, where old rails are available, this form results in great economy of first cost. For this reason it was found best to adopt this type at the Reunion mines, and is represented in Fig. 2. It was made from an old cylindrical boiler and contains some 50 tons of old rails. The intermittent supply of steam enters by the pipe D, and the steady current of steam reaches the turbine through the pipe E.

Water being the substance having the greatest capacity for heat, it is evidently desirable to use it as the "heat fly-wheel" to the exclusion of all other materials, but as water is a very bad conductor of heat, in order to communicate a large quantity of heat to a given mass of water in a short space of time, it is necessary that the water be arranged in very thin sheets, or that an active circulation be produced in it, so as to bring the whole mass rapidly in contact with the source of heat. The water types of accumulators have been designed to meet these requirements.

3. Automatic Agitation of Water.

The apparatus is formed of a horizontal cylindrical boiler (Fig. 3) nearly full of water. Several horizontal pipes, A, of elliptic section and large area are arranged in the boiler or tank, and reach from end to end with vertical passages B between them. The steam enters these pipes and passes into the passages B by a number of small openings in the walls of the pipes A. The steam, in discharging through these openings into the passages B, causes an extremely rapid movement in the liquid which flows up the passages B and descends in the passages between the pipes and the walls of the tank. The necessary energetic circulation of the water is thus obtained.

Sheet iron plates are arranged over the passages B to direct the flow of the water in a horizontal direction and prevent its being thrown up into the dry pipe. The apparatus is furnished with a safety valve and discharge valve actuated by a float when the water rises to a given level.

During the discharge of steam by the primary engine, an energetic boiling of the liquid takes place. When the exhaust stops, the water becomes more steady and gives back, as steam, the heat contained in it in a manner similar to an ordinary boiler.

The dimensions of this apparatus are relatively moderate. An accumulator twenty feet long and six feet six inches in diameter, containing ten tons of water, allows of the utilization of 10,000 pounds of steam per hour, when the primary engine has stops of as much as, and not over, one minute.

A 350 H. P. accumulator of this type is under construction for the Bethune mines, Pas de Calais.

4. Mechanical agitation of water.

This active circulation of water can be obtained by means of mechanical power—for instance, a pump raising the water to the top of the accumulator, the discharge pipe emptying into a perforated tank, through which perforations the water flows back to the accumulator.

CALCULATION OF THE DIMENSIONS OF AN ACCUMULATOR.

The weight of materials necessary to the regeneration of steam increases in proportion to the quantity of steam per hour and the duration of the stops. Suppose, for instance, it is desired to construct an accumulator of the water type. During each stoppage of the primary engine the accumulator must give up a steam equal to

$$P = \frac{Q\,t}{3600}$$

Q, being the weight of steam per hour and t, the duration of each stoppage expressed in seconds.

These P pounds of steam contain at atmospheric pressure 966 B. T. U. per pound. Whence the accumulator must be figured to be capable of giving up $P \times 966 = N$, B. T. U. within the allowable limits of variation of pressure.

Calling Z, the variation of pressure corresponding to these pressure limits existing between the commencement and end of each period of rest, and if x be the required weight of water forming the "heat fly-wheel," we have (the specific heat of water being unity)

$$x = \frac{N}{Z} = 966\,\frac{P}{Z}$$

If, in place of water, the "heat fly-wheel" is composed of cast-iron, of which the specific heat is about 0.11, a mass of iron will be required nine times as great as we have obtained above. For example, the steam consumption of the secondary engine being 2,200 pounds per hour (corresponding to about 77 effective horse-power), the duration of each stop being one minute (or 60 seconds) and the allowable range of temperature 10 degrees F., then we have

$$P = \frac{2200 \times 60}{3600} = 36.6$$

and the accumulator must deliver

$$36.6 \times 966 = 35{,}400 \text{ B.T.U.}$$

Whence, the weight of water necessary to deliver this quantity of heat per minute, with a range of temperature of 10 degrees F., is

$$\frac{35400}{10} = 3540 \text{ pounds, or about } 1.5 \text{ tons.}$$

For cast-iron, a weight of $\frac{1.5}{0.11} = 13.75$ tons, is required,

ACCESSORIES TO THE ACCUMULATOR.

Each accumulator is provided with fittings and accessories which make the turbine and the main engine entirely independent of one another.

1. Free Air Relief Valve.

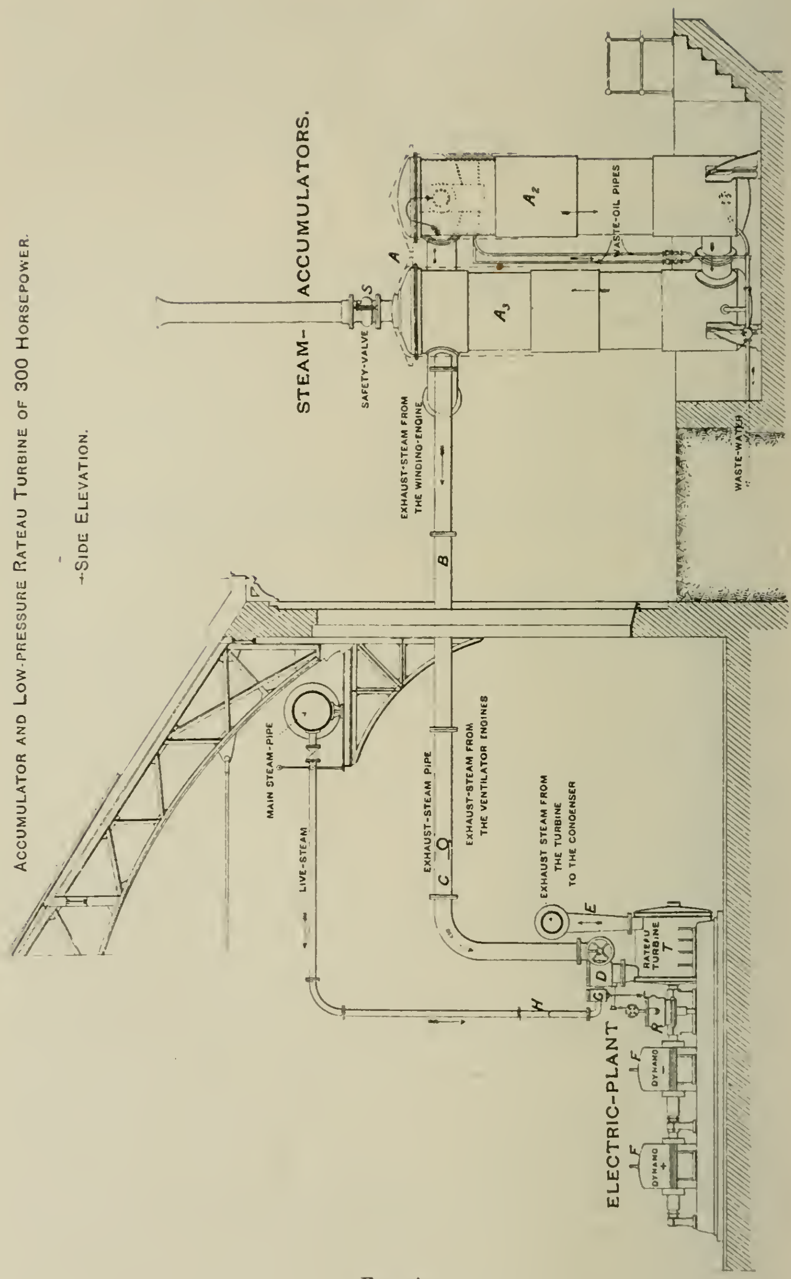
This valve is placed on the accumulator so as to allow the steam from the primary engine to escape directly into the atmosphere, or into the condenser, if the turbine, by reason of light load or otherwise, does not require all the steam exhausted by the main engine.

A double-beat valve is usually employed in order to obtain a large area of discharge with a small lift, and also to balance the thrust of the steam, as shown in Fig. 3.

2. Automatic Expansion Valve.

This apparatus is provided so that live steam from the boilers may be admitted to the turbine, should the main engine be temporarily shut down, or if sufficient exhaust steam is not available at times when the turbine is required to continue to operate. Under these conditions the automatic expansion valve opens and makes up the deficiency when the pressure in the accumulator falls below a certain fixed value, depending on the requirements of each particular case. This is indicated in Figs. 4 and 5. By means of these two valves the engine and turbine can be operated entirely independently of each other.

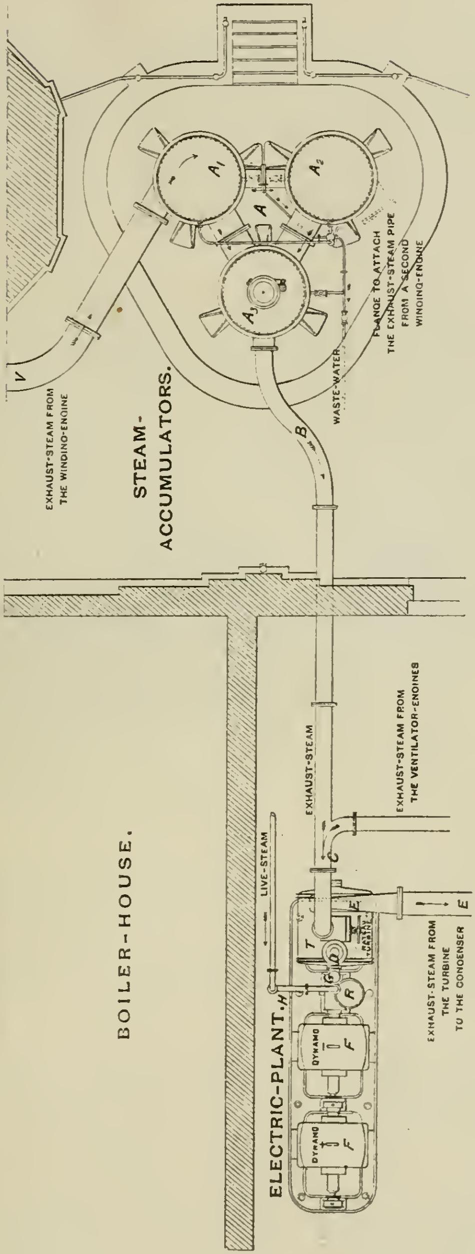
No inconvenience or difficulty arises in utilizing live steam from the boilers, when the primary engine is not operating. On the contrary, from the point of view of the boiler, it is an advantage, as it tends to make the operation of the boilers more regular. Of course, in such a case the steam is not utilized at its initial pressure,



Accumulator and Low-pressure Rateau Turbine of 300 Horsepower.

Side Elevation.

Fig. 4.


EXHAUST-STEAM FROM THE WINDING-ENGINE
V
STEAM-ACCUMULATORS.
A_1
A_2
A
A_3
B
WASTE-WATER
FLANGE TO ATTACH THE EXHAUST-STEAM PIPE FROM A SECOND WINDING-ENGINE
BOILER-HOUSE.
ELECTRIC-PLANT.
H
LIVE-STEAM
EXHAUST-STEAM
EXHAUST-STEAM FROM THE VENTILATOR-ENGINES
C
T
D
G
R
DYNAMO
F
DYNAMO
F
E
EXHAUST-STEAM FROM THE TURBINE TO THE CONDENSER

Scale, 100 Inches to 1 Inch.

Fig. 5.—Plan.

and consequently there is a certain loss of efficiency; but this is in the nature of an emergency operation, and in cases where it is likely to be of common occurrence another arrangement, to be described later, is adopted, which completely avoids this difficulty.

3. Steam Check Valve.

This appliance is provided for the purpose of shutting off the accumulator from the turbine when the main engine is shut down and the turbine is being supplied with live steam only. It is similar to the atmospheric relief valve.

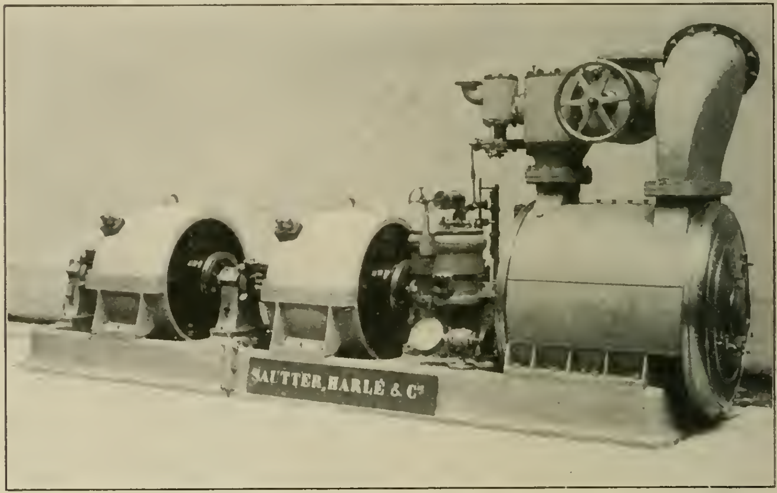


Fig. 6.

4. Water Check Valve.

This is shown in Fig. 3, near the center of the engraving, and is employed on accumulators of the water type only. It is used to prevent the water returning towards the main engine through the exhaust supply pipes when the engine is shut down for any length of time.

5. Automatic Trap.

The water entrained in the exhaust steam or from condensation is discharged by an automatic trap, usually an inverted syphon or an automatic valve operated by a float inside the apparatus.

LOW PRESSURE TURBINES.

It is evidently possible to utilize the regulated flow of steam in a reciprocating engine, but such an engine would be of very large size, the initial cost would be high, and moreover, its thermal efficiency would be low on account of the great amount of cylinder condensation that would occur.

It is entirely unimportant what system of turbine is employed. The type developed by Prof. Rateau is of the multicellular direct action type. It is composed of a number of very light sheet steel wheels carrying circular buckets and revolving between circular diaphragms. These diaphragms, which also carry the guide blades, are set into grooves in the interior of the turbine casing. The bearings are exterior to the turbine and a special system of mounting prevents all entrance of air.

The steam consumption of this turbine is very low. In conditions where a piston engine requires 50 pounds of steam per brake horse power, the turbine requires only 31.5 pounds. It is here presupposed that the initial pressure is that of the atmosphere and the back pressure equivalent to 27 inches vacuum.

Turbines lend themselves to a number of interesting applications, the principal of which is the generation of electricity. The installation at Bruay is an example. The low pressure turbine, Fig. 6, supplied by the steam accumulator, drives two dynamos operating a three-wire system at 500 volts.

—TURBINE-DYNAMO OF 300 HORSEPOWER.

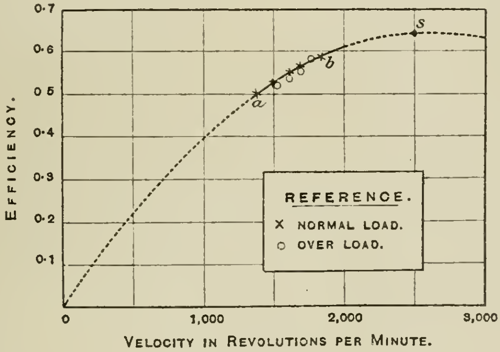


FIG. 7.

In the particular case of low pressure turbines, the influence of a good vacuum in the condenser is considerable; in fact, the more perfect the vacuum, the better the steam will be utilized. The diagram (Fig. 7) shows the variation of the efficiency of the Bruay turbine with the speed of rotation. It will be seen from this curve that the combined efficiency at 1,800 revolutions per minute reaches 58 per cent, and that it rises to over 60 per cent if the speed is raised to about 2,000 revolutions per minute. Tests made in November, 1903, after fifteen months' operation showed no falling off in the combined efficiencies.

The following table shows the steam consumption required to give a horse power electric at the terminals of the generators:

Absolute pressure of steam, at admission.	30 lbs.	15 lbs.	7.5 lbs.
Vaccuum in the Condenser of 27.6 inches......1.14 lbs	20.7	26.4	36.3
" " " " " 26 0 " .....1.85 "	23.6	31.7	47.3
" " " " " 24.6 " ......2 56 "	26.4	36.3	61.6

The first horizontal line of the table corresponds to the case where a surface condenser giving a vacuum of 27.6 inches is used. The second to an ordinary jet condenser giving a vacuum of 26 inches, and the third to an ejector condenser giving a vacuum of 24.6 inches. These vacuums are easily obtained in practice.

The central vertical column corresponds to the usual conditions when the steam is supplied to the turbine at atmospheric pressure. The first column gives the consumption in the case where the primary engines exhaust against a gauge pressure of fifteen pounds, in order to take advantage of the superior efficiency with which it can be used in the turbine, while the third column represents the condition where it is desirable not to disturb the condensing operation of the main engines, and consequently to utilize steam exhausting from them at about 7½ pounds absolute.

It will be seen from this table that when exhaust steam at atmospheric pressure is used, an electric horse power can be produced at the terminals of the dynamo for 26.4 to 36.3 pounds per hour, depending on the vacuum obtainable, and that when the turbine is supplied with steam at a pressure of only 7.5 pounds absolute, an electric horse power can be given for about 36 pounds of steam per hour under good vacuum conditions.

GOVERNOR.

A very sensitive centrifugal governor controls the speed of the turbine so that the variations do not exceed 1 per cent, notwithstanding the fluctuations of pressure in the accumulator and of the load on the dynamos.

COMBINED HIGH AND LOW PRESSURE TURBINES.

At times when the low pressure turbine is supplied with live steam direct from the boilers through the automatic expansion valve, the steam consumption per horse power is evidently higher than would be realized by a machine designed to operate at the full boiler pressure; for example, 33 pounds instead of 22 to 26 pounds per hour.

When the operation of the primary engine is not very irregular, the total time during which live steam is required is relatively very small, so that the somewhat larger steam consumption during this time has hardly an appreciable influence on the average economy. On the other hand, if the turbine be required to operate during long periods of rest of the primary engine, for example, to operate 24 hours a day, while the primary engine runs 10 hours only, the increased consumption is no longer negligible.

The turbine is then arranged so that under all conditions the highest economy is assured by adding a high pressure section to the turbine, arranged to receive the live steam from the boilers when the primary engine is shut down. After passing through the high pressure section, the steam enters the low pressure turbine. Thus the turbine operates with equal economy either with the exhaust steam from the primary engine or with live steam, from the boiler, or with both together.

The two sections of the turbine must be considered as an ordinary high pressure turbine arranged to receive at any moment, and to utilize in the most economical manner the exhaust steam from a primary engine. It should be clearly understood that the live steam is admitted automatically, as required, by an appropriate governor. With an ordinary vacuum, such a turbine will not require, at full load, over 16.5 pounds of steam per electric horse power per hour at the switchboard, at a gage pressure of 100 pounds per square inch, and as stated above, from 26 to 36 pounds, depending on the vacuum, when it is supplied with steam at atmospheric pressure only.

By means of this simple arrangement, a machine which always operates to the best advantage is obtained. At times when no exhaust steam is available it is simply an ordinary high pressure turbine properly utilizing live steam. When the supply of exhaust steam begins, a proportional reduction takes place in the quantity of live steam required. A combined high and low pressure turbine can draw its steam supply not only from two sources at different pressures, but from three or four—an advantage which cannot be as easily arranged in the case of a reciprocating engine.

It is unnessary for the supply of exhaust steam to be sufficient, at least for short periods, to give the full load of the turbines; it may be only a portion of the total.

APPLICATIONS IN STEEL WORKS AND FACTORIES.

The original installations were made in mines, but the utilization of exhaust steam can be equally well carried out in steel works, in metallurgical works, and generally in any industry which employs intermittent running engines—as for example, rolling mills and steam hammers. For this class of engines, the use of condensation or multiple expansion presents the same difficulties as mentioned above, so that the steam economy is low. The system consequently can be employed in steel works equally well as in mines. But it offers far greater advantages because most of the engines are running night and day.

Instead of producing electric power, the energy in the turbine may be employed to drive high pressure ventilating fans or centrifugal air compressors.

Engines consuming 40,000 to 45,000 pounds of steam per hour are frequently found in rolling mills. The turbine will not require over 31 pounds of steam per electric horse power per hour, so that the exhaust steam from such an engine can be used to produce over 1,500 electric horse power. Generally, however, the exhaust from several engines can be delivered to a central station, where it can be used in a number of turbines. If Q be the weight of dry steam in pounds thus delivered per hour, the electric horse power which can be developed will be equal to $\frac{Q}{31}$.

It is easy to see that in modern steel works an addition of several thousand horse power can be rendered available by the Rateau system.

ADVANTAGES OF THE SYSTEM WHERE A CENTRAL CONDENSING SYSTEM IS ALREADY INSTALLED.

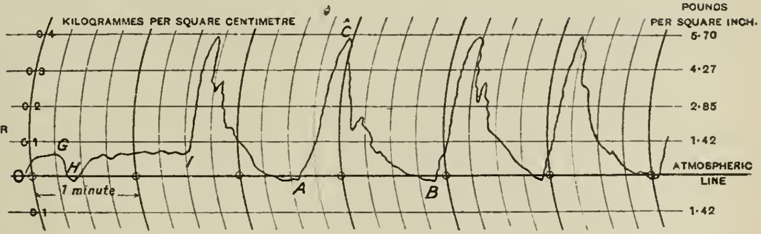
In cases of this kind we place the accumulator and turbine between the primary engine and the condenser. Outside of the better efficiency in which the steam is used by this means, there is the additional advantage in the case where the steam is delivered to the turbines at slightly above atmospheric pressure of avoiding the leakage of air into the exhaust system. But it must be pointed out that turbines can also be operated with steam at a pressure below the atmosphere if it is not desirable to raise a back pressure on the primary engines on account of decreasing their power.

It would seem at first extraordinary that the steam can be utilized better by Rateau's system than by simply operating the primary engines condensing. But it is not difficult to show that the advantage is very considerable. This advantage is due to the fact that in a turbine the steam can be expanded down to the very last limit, and the turbine will give an excellent efficiency, while the contrary is true in the case of reciprocating engines.

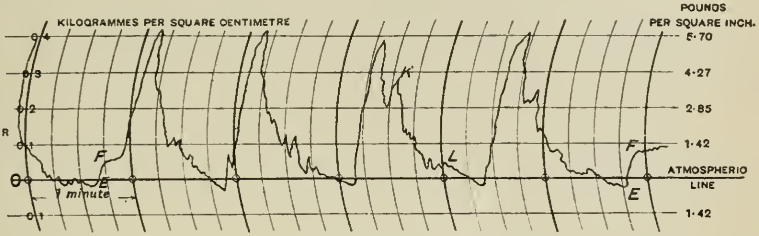
Steam turbines normally develop 65 to 70 per cent of the energy theoretically available by expanding the steam from atmospheric pressure down to the condenser vacuum, while reciprocating engines under the same conditions only develop 35 to 40 per cent of that energy.

In other terms, the whole installation utilizes the available heat in the steam, leaving the boilers better when reciprocating engines

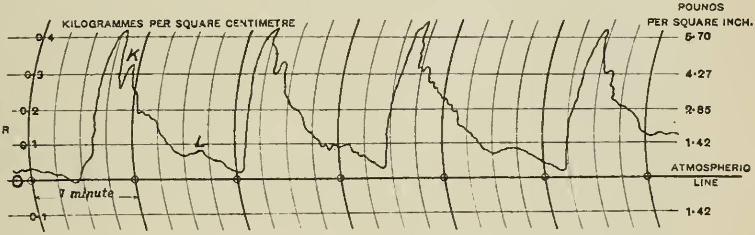
PRESSURE-DIAGRAMS TAKEN FROM THE STEAM-ACCUMULATOR.



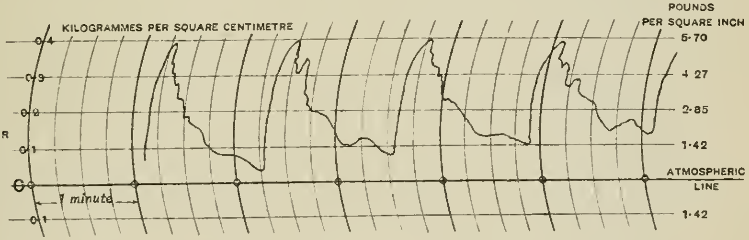
P = 0·89 Kilogrammes per Square Centimetre
p = 0·266 Kilogrammes per Square Centimetre
Te = 198 Horsepower.
I = 4,950 Kilogrammes per Hour.



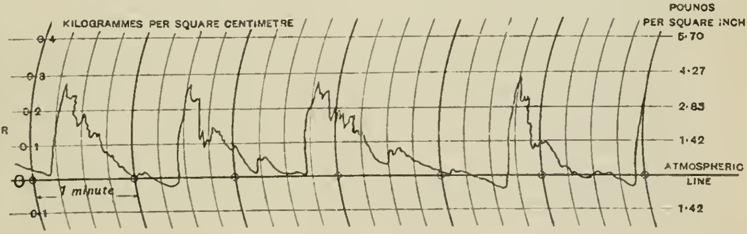
P = 0·85 Kilogrammes per Centimetre
p = 0·230 Kilogrammes per Square Centimetre
Te = 195 Horsepower
I = 4,700 Kilogrammes per Hour



P = 0·63 Kilogrammes per Square Centimetre
p = 0·255 Kilogrammes per Square Centimetre
Te = 115 Horsepower.
I = 3,460 Kilogrammes per Hour



P = 0·54 Kilogrammes per Square Centimetre
p = 0·258 Kilogrammes per Square Centimetre
Te = 85 Horsepower
I = 2,970 Kilogrammes per Hour.



P = 0·60 Kilogrammes per Square Centimetre
p = 0·326 Kilogrammes per Square Centimetre
Te = 65 Horsepower
I = 3,300 Kilogrammes per Hour.

Fig. 8.

are used for high pressure and turbines for low pressures. The truth of this is proved in the following manner:

Let N be the mean steam consumption of the primary engines per effective horse power per hour when operating non-condensing. Then the advantage

$\left.\begin{matrix}\text{a—when they are simply operated condensing,}\\ \text{b—when Rateau's system is applied,}\end{matrix}\right\}$ is as follows:

When ordinary condensation is employed, about 15 to 20 per cent of the steam is saved. Let us take the latter figure. Then for each effective horse power produced by the primary engines, a quantity of high pressure steam equal to 0.2 N becomes available. Suppose this steam be employed in a first class reciprocating engine to generate electricity, for example: The steam consumption of a generating set with a compound or triple-expansion engine is not less than about 16.5 pounds of steam per electric horse power, so that the power rendered available will be

$$\frac{0.2\,N}{16.5} = \frac{N}{82.5}$$

With our system, as the primary engines still operate non-condensing, they will consume the same weight of steam for the same useful work produced. But the exhaust steam can produce in a low pressure turbine an effective horse power for 31 pounds of dry steam per hour.

But if a weight of steam N is exhausted from the primary engines, there will be only 80 per cent of this as dry steam, assuming 20 per cent of the steam condensed in the engines and pipes. This weight of steam is capable of furnishing useful work in electric horse power amounting to

$$\frac{0.8\,N}{31} = \frac{N}{38.75}$$

Thus, for each useful horse power developed by the primary engines, for a steam consumption of N pounds per hour when operating non-condensing, $\frac{N}{82.5}$, useful horse power is obtained, at the most, with the ordinary system, while with Rateau's system more than double this power is obtained. The ratio of these two figures, moreover, is independent of the higher or lower economy of the primary engines.

The diagrams (Fig. 8) are traced automatically, and show the conditions of the steam pressure in the accumulator. The heavy, horizontal line shows the atmospheric pressure, and generally the pressure is above that of the atmosphere, and may be 5.7 pounds per square inch, or even more, momentarily. The pressure falls from the consumption of the steam by the turbine.

The value of P, expressed in kilogrammes per square centimeter at the several marginal notes, is the pressure of the inflowing steam to the turbine. The value of I is the weight of steam used in the turbine, and varies with the vacuum obtained by the condenser.

As shown in these diagrams taken at the Bruay plant, the intervals of time between the peaks of pressure, which correspond to the times of the operation of the winding engines, is about one minute. The maximum back pressure on the primary engine is 5.7 pounds per square inch. The top member of the diagram indicates that 198 electric horse power was obtained by the use of 4,950 kilogrammes of exhaust steam, with a range pressure of 0.890 kilogrammes per square centimeter (corresponding to 12.7 pounds absolute) to 0.266 kilogrammes per centimeter back pressure at the condenser.

THE ACCUMULATOR AS AN AID TO THE CONDENSER.

It will be observed that the accumulator can be employed, without a turbine, to steady the discharge of steam to the condenser. The satisfactory operation of central condensation connected to an intermittent running engine is due to long exhaust pipes and the presence of a certain quantity of water in the pipes, which acts as a heat fly-wheel. The accumulators can therefore be advantageously used to enable the condensers to operate under a less variable load. Then there is no objection to the employment of jet or of ejector condensers. This applies principally to mine shafts where, besides the winding engine, several other engines such as fan engines, compressors, etc., are operated, and which not infrequently have a total steam consumption greater than the winding engine itself. An accumulator placed between the winding engine and the condenser will then prevent the irregularity of the exhaust from that engine, affecting the vacuum given by the condenser and so insure more perfect operation.

ECONOMIES RESULTING FROM THE USE OF RATEAU'S SYSTEM.

These economies are of two kinds:

1st—Lower initial cost of the apparatus, and

2d—Reduced operating costs.

I. Initial Cost.

The saving here is, that no additional boilers must be installed to develop the power required. Rateau's system only needs a steam accumulator, which is far less expensive than boilers of equivalent capacity. The less cost of a turbo-dynamo, compared with a reciprocating engine and generator of the same power, is also to be considered.

These economies vary in importance, depending on the additional power required, the size of the accumulator, the cycle of operations of the primary engine, and the general character of the layout. Precise figures cannot be given, more especially as the price of engines differ considerably in different countries.

2. *Reduced Operating Costs.*

These savings result principally from the fact that no additional coal is burnt while the primary engine is in operation, and also because, there being no additional boilers required, there are no interest and depreciation charges on them.

For illustration, a 500 electric horse power, if operating ten hours a day at an average of 80 per cent of rated output, will realize the following economies:

1. Saving of coal in 3,000-hour year, at $2.00	$6,900
2. Two Firemen at $2.00 a day	1,200
3. Less fixed charges, say at 10 per cent	1,250
Making an annual saving of	$9,350

Of course, in a plant running 24 hours a day, the saving will be proportionately greater; but in the case of coal mines, where coal costs very little, the saving is not so large.

It may be that these economies, even if the interest and depreciation charges are deducted, represent a very large percentage of the initial cost of the plant; so much so, that the other economies realized will completely pay for the plant in a short time.

ADVANTAGES OF THE SYSTEM.

Easy to install; takes up very little space, and costs much less than a reciprocating engine installation of the same power.

No attendance nor repairs on the steam accumulator.

The energy recovered by means of the turbines can be used for driving dynamos, centrifugal pumps, and fans of low or high pressure, all extremely simple apparatus and easily taken care of.

Great economy in operation. No coal or additional boilers required.

The arrangement of the bearings outside the turbine prevents all oil reaching the condenser.

Possibility of employing combined high and low pressure turbines, so that the steam, whether high pressure or low pressure, is always utilized to the best advantage.

Generally a rational and more perfect utilization of the heat energy contained in the steam.

Installations of this nature are in operation or in course of erection at the following places:

350 H. P.—Bruay mines, France.
600 H. P.—Reunion Steel Works, Spain.
500 H. P.—Firminy mines, France.

2,700 H. P.—Donetz Steel Works, Russia.
750 H. P.—Romback Steel Works, Germany.
700 H. P.—Steel works of Poensgen, Germany.
600 H. P.—Houssu mines, Belgium.

DISCUSSION.

Mr. Warder—A great deal of the progress in modern metallurgical work is due to the invention of the Siemen's regenerative furnace. This improvement consisted in passing the hot waste products of combustion through chambers of brickwork, containing masses of brick which absorbed a large portion of the heat from the waste gases; at suitable intervals, by means of valves, the products of combustion were diverted from the first chamber into another and similar one, while the air for the combustion of the fuel of the furnace is passed through the first chamber, and thus reheated to a high temperature, results in fuel economy and a much greater heat in the furnace. The special point to be considered is the recovery of a great portion of the heat from the products of combustion by its first being absorbed by means of brick work, and subsequently the giving up of this heat to the passing current of air to be used in the combustion of the fuel for the furnace. It appears that there is a notable analogy between the principle of the Siemen's regenerative furnace, and the device described by the speaker of the evening—namely, the regeneration of the heat in the exhaust steam from the primary engine, which would otherwise go to waste. The conditions are different, however, in that, instead of using chambers containing masses of brick work, the exhaust steam is more or less taken up, condensed in a closed vessel containing water, termed the accumulator, which, when called upon, because of the cessation of action and supply of exhaust steam from the primary engine, will give up its heat (or steam) to the low pressure steam turbine. It is to be noted that the special application of the accumulator, described this evening, is in connection with engines whose work is of an intermittent character, and that, in general, the exhaust steam at about or above atmospheric pressure, is utilized in a low pressure steam turbine in connection with a condensing apparatus. While the primary engine is in operation the exhaust steam that is in excess of the needs of the steam turbine is condensed, and the heat stored up in the accumulator. This steam is yielded up to the service of the turbine when needed because of the stopping of the primary engine and the cutting off of the supply of exhaust steam.

Mr. C. A. S. Howlett—I would like to ask Mr. Battu if there are any such plants in use in this country?

Mr. Battu—No; but I have every reason to believe there will be at least one very important plant in the near future.

Mr. Smoot—How do you decide what shall be the controlling factors for pre-determining the vacuum?

Mr. Battu—There is no necessity for fixing upon a special vacuum; but the higher the vacuum the better utilization of steam you have, especially in the case of a turbine.

Mr Smoot—Why do turbines require such high vacuum?

Mr. Battu—It is not compulsory that turbines work against a very small back pressure, as they can be worked at any vacuum. In the case referred to in my paper, the vacuum of the central condenser at Bruay is not more than 25 inches; but as turbines employ the expansion of steam to the limit of the condenser, it is very important to push that limit as far as possible. You can see from the table* showing the consumption of steam that in the case where the exhaust is employed at atmospheric pressure with a condenser giving 27.6 inches, only 26.4 pounds of steam is needed for a horse power electric at the brushes, and that with a vacuum of 24.6 inches, then 36.3 pounds of steam is required. A well established condenser, working against an exhaust of a good-sized power engine, ought not to employ more than 1 per cent of the power. For illustration, the Fisk street station of the Commonwealth Electric Co.; there the power necessary to drive the auxiliaries and maintain a 28½-inch vacuum is not quite 1 per cent. It is to be understood that if the water supply for circulation is in an abnormal situation, the power for the pump giving the circulation of water is to be added. I do not understand why the use of a high vacuum should be criticised, when there is water enough to maintain it. It seems to me that it depends on the value of the condenser itself, and as it is a known fact that constructors can make those condensers and guarantee a vacuum of 28 inches, without increasing the first cost in a prohibitive way, is not the choice of the type of condenser a great factor in those criticisms? In the case of an accumulator combined with a low pressure turbine, the choice of the condenser is left completely out of the question. The important thing is to have a good vacuum if you want a high efficiency. If you do not care for that high efficiency, you can have such back pressure as you desire.

Mr. Alvord—Am I right in understanding you, that you would place the economy obtained by the turbine employing the regulated exhaust superior to the same amount of power developed in the primary engine?

Mr. Battu—I will refer to the table of consumption of steam contained in this paper. It will be seen that if the main engine is of the type of an ordinary twin hoisting engine, or of the type of reversible rolling-mill engine exhausting at atmospheric pressure, the quantity of steam required to obtain a useful horse power in actual work will be an average of 90 pounds per hour ; or, say 60 pounds for a very modern engine having all the latest improvements, and up to 120 pounds for engines of less modern design and construction. Then, in the first case, if we suppose the condensation of the steam in pipes and cylinders to be 20 per cent, we have 48 pounds of steam going through the turbine, and if we suppose a vacuum of 26 inches (referring to the table I mentioned) we have a horse power electric at the brushes for 32 pounds of steam. The horse power in this case, obtained by the 60 pounds of steam, will be 1 horse power in the main engine and about 1 ½ electric horse power by means of the turbine.

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* Page 486.

In the second case I mentioned we have 120 pounds of steam, minus 20 per cent. condensation—say 96 pounds per hour, working in the turbine with a vacuum of 26 inches; referring again to the table we have then, for 120 pounds of steam coming from the boilers, 1 horse power in the main engine and 3 horse power electric at the brushes of the turbo-dynamo.

Mr. Junkersfeld—If I understand the paper correctly most of the advantages and most of the results referred to are with engines working under heavy load.

I would like to ask whether the scheme has been tried in which much of this auxiliary apparatus which is so objectionable in large plants is eliminated? There is a scheme being advocated somewhat by a few American engineers, consisting of the use of a low pressure turbine in series directly back of the low pressure cylinder without this accumulator, allowing the turbine and engine to work in parallel, and the turbine doing such work as the volume of range of temperature will permit. Has any such scheme been tried abroad?

Mr. Battu—In answer to Mr. Junkersfeld's remarks I will say that this auxiliary apparatus that Dr. Rateau calls a steam accumulator has for its object to regularize the flow of steam, or flows of of steam, varying in pressure and in volume. Its use is then limited to those engines which have an intermittent exhaust.

In the matter of replacing the low pressure cylinder of a reciprocating engine by a steam turbine, we are in the presence of two problems :

First, the engine is a continuous running engine, and then the exhaust is regular. In this case no steam accumulator is needed.

In the second case, if we have non-continuous running engines the exhaust is irregular and cannot be employed through any sort of engine. The method of Dr. Rateau allows then, by the use of a steam accumulator, to employ the flow of steam regulated by his apparatus.

Mr. Junkersfeld—Has the scheme of the first case, with continuous running engine, been tried?

Mr. Battu—As far as I know this idea is old—at least ten years. As to its application I would like to mention that Dr. Rateau advocates for ship propulsion triple expansion reciprocating engines exhausting into turbines. A torpedo boat of this kind has been built, and the trials were very successful, the average speed being 26.5 knots.

Mr. Junkersfeld—I mean particularly on constant running engines.

Mr. Battu—I do not know of an application of that type on any other engine, except on the boat I mentioned.

Mr. Blumenthal—With the intermittent supply of steam in a case like this, what is the variation of speed in your turbine?

Mr. Battu—Within 1 per cent.

Mr. Howlett—You stated that the electric horse power of the Bruay turbine is 300; what is the horse power of the primary mover?

Mr. Battu—In supposing that the winding engine at Bruay hoists four tons of coal at once, and makes 50 trips per hour, we have for the depth of 230 meters an average useful effort of 175 H. P. If we allow the hoisting engine a steam consumption for the average useful horse power hour to be 45 kilogrammes, the exhaust is then 7,875 kilogrammes. If we assume 20 per cent of condensation in pipes and cylinders, the quantity of steam flowing through the turbine will be 6,300 kilogrammes per hour. Under the conditions, with a poor vacuum the low pressure turbo-generator will give an output of 330 electrical horse power, and with a very good vacuum, 450 horse power. This shows that the utilization of the exhaust steam gives a great deal more power than from the primary hoisting engine.

Mr. Pearce—How long does the steam turbine continue to operate after the primary engine has stopped?

Mr. Battu—The stoppage of the Bruay turbine, if I remember correctly, is about one minute. The steam accumulator is calculated in such a manner that the live steam is not to be applied for before that time. Nothing would be easier, as you can see by the calculation of the steam accumulator, of having stoppages of two or three minutes.

Mr. Bement—I would ask two questions of the author;

First—Assuming two turbines discharging to good vacuum—one receiving steam at atmospheric pressure and the other at 150 pounds—what would be the comparative heat efficiency, taking for granted that each machine was designed for its respective service?

Second—What would be the comparative size of two such turbines to give the same horse power output?

Mr. Battu—I am glad that Mr. Bement's interesting questions give me an opportunity to present here Dr. A. Rateau's definition and theory of the efficiency of steam turbines.

Replying to Mr. Bement's first question, I will say that it is essential that the word efficiency should be clearly defined, in order to avoid any misconception. Mr. Rateau uses the expression "theoretical consumption of the perfect machine" to denote the maximum work which the steam is capable of yielding when starting from the saturated or superheated condition in which this steam is delivered to the engine, and expanding adiabatically with no loss of admission pressure P to exhaust pressure p. By comparing the actual consumption of steam, as measured during the tests of the machine, with this theoretical consumption of the perfect machine for identical conditions of pressure, and similar states of the steam, the net efficiency of the machine is obtained. After special study of the question, Dr. Rateau has been able to draw a curve of theoretical consumption, and to derive from it the following empirical formula for use when the steam is saturated and dry at admission:

$$\mathrm{E} = 0.85 + \frac{6.95 - 0.92 \log \mathrm{P}}{\log \mathrm{P} - \log \mathrm{p}}$$

This formula gives the consumption K in kilogrammes per horse power hour of 75 kilogramme metres as a function of the absolute pressure P and p expressed in kilogrammes per square centimeter.

In British measures this formula becomes:

$$\mathrm{K} = 2.13 + \frac{16.20 - 2.05 \log \mathrm{P}}{\log \mathrm{P} - \log \mathrm{p}}$$

K in pounds per horse power hour, P and p in pounds per square inch. The diagram in this paper is actually well known, having been published by Dr. Rateau in his report on steam turbines to the Paris International Congress of 1900. This diagram will readily afford interesting information, particularly if it be necessary to estimate the consumption of steam with a given machine to obtain a certain useful effect. In that case, the theoretical consumption per horse power hour given by the diagram should be compared to the exact consumption of steam actually observed with the machine, and, of course, referring to the particular number of electrical horse power developed by the dynamo driven. The relation between these two figures of consumption gives the combined efficiency of the group, and therefore takes account of all the losses of the steam engine and of the driven mechanism. This combined efficiency is merely the product of the efficiency of this prime mover multiplied by the efficiency of the machine driven. If the steam admitted to the turbines is superheated, then, of course, in estimating the theoretical consumption, the extra calorific energy corresponding to the superheat must be taken into account; but for the exact estimation of this extra energy we have not as yet adequate precise knowledge of the specific heat of the vapor of water. At the present time, we have merely the figure obtained by Regnault after very cursory experiments (0.48), a figure which is merely a rough approximation.

Dr. Rateau has suggested that from his experiments he will be able to prove that the true specific heat of steam is not constant, as has been usually supposed up to the present. It varies inversely as the amount of superheat, and is probably approximately unity for very small values of superheat, and approaches 0.40 for large amounts of superheat.

The efficiency of a turbine may be calculated *a priori* when a preliminary study has been made of the practical coefficients which must be introduced into the theoretical formula. Dr. Rateau calculates this efficiency with a remarkable degree of accuracy by dividing the losses of the machine under two headings—1st, the internal losses which are produced by friction and eddying of the steam in the fixed and moving vanes; 2d, the external losses which correspond to the leakages of steam in the play between the fixed and moving parts; and to the friction of the wheels upon the steam and to the friction of the bearings. The first kind of losses give rise to the "internal efficiency," which may therefore be called the "hydraulic efficiency," by adopting the use of the term employed for hydraulic turbines. This internal efficiency depends upon the more or less perfect form of the vanes, and also to the relation between the peripheral speed of the moving vanes, and the speed of flow of the steam. It is possible to draw a curve showing the efficiency as a function of the peripheral velocity, and therefore it is easy to at once assign the degree of efficiency which a given turbine will realize.

Once having fixed the internal efficiency, then, in order to obtain the net efficiency, we must deduct the losses by leakage as well as the losses by friction of the wheels upon the steam, and also those in the bearings. Let us take, as illustration, a Rateau turbine of 1,500-brake horse power upon the shaft with a speed of 1,500 revolutions per minute. By means of practical coefficients found by experience, internal efficiency can be calculated and can rise to 69 per cent; on the other hand, the losses by leakage and friction in the bearings absorb 1.5 per cent of the normal power, and the losses due to friction of the wheels upon the steam amount to 2.5 per cent at most, making a total of internal losses of 4 per cent. The net efficiency upon the shaft at the speed stated will then be of $0.69 \times 0.96 = 0.66$. From this value of efficiency it is easy to calculate the consumption of steam per horse power hour which would be required by the turbine under conditions of pressure and of superheat of the steam already determined. All calculations for designs of turbines that Dr. Rateau has made by this means have always proved correct within 1 to 2 per cent, in actual practice.

Mr. Bement can, with the exposed method, calculate easily the efficiency of the turbines at atmospheric and at 150 pounds pressure.

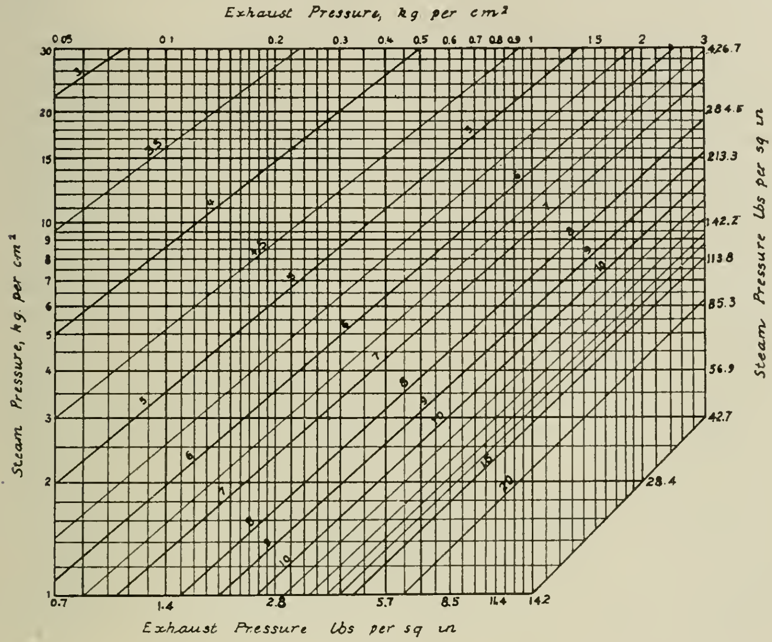


FIG. 9.

In reply to Mr. Bement's second question:

The dimensions of the turbine do not at all increase proportionally to the volume of steam to be utilized. The increase of the distributors is only to be calculated, and in such a manner that the total flow of steam can pass through them with a suitable velocity.

Mr. W. J. Warder—Is not one of the great advantages of steam turbine in operating under low pressure to have efficiencies greater than from reciprocating engines under the same conditions?

Mr. Battu—The great size of a reciprocating engine, working under such conditions, of steam at atmospheric pressure, to the vacuum of the condenser, with the importance of condensation in those large cylinders, and the throttling of steam, would give for the use of the steam a very poor efficiency; in fact, I do not think it would be practicable, commercially speaking.

Mr. Pearce—I would like to ask Mr. Battu if my impression is correct, that the principal application of this system is in connection with engines utilizing steam intermitently?

Mr. Battu—Yes; rolling mills, hoisting engines, etc.

Mr. Pearce—The object is to utilize the otherwise wasted heat from the primary engine doing intermittent work, is it not?

Mr. Battu—Yes.

A visitor—I wish to ask how you make use of high pressure steam when the low pressure steam has given out? Do you use it on the same turbine or an auxiliary one?

Mr. Battu—Two distinct turbines are employed—a high pressure turbine and a low pressure turbine; the low pressure turbine working exclusively with steam at a suitable pressure, and the high pressure turbine working at a given pressure. The exhaust of the high pressure turbine can be directed into the low pressure turbine or sent direct to the condenser. Both turbines work on the same shaft.

Mr. H. R. Wellmann—You spoke of shutting down 1½ minutes. How many minutes maximum can you allow with the Rateau system?

Mr. Battu—After a period of say, for illustration, three minutes, there is no need of increasing the size of the accumulator to obtain the steam needed by the turbine. It is far better to employ the live steam that the safety valve of the boilers would let out, the main engine calling for no steam.

Mr. Smoot—How long a period would it be possible to use the accumulator in a commercial installation?

Mr. Battu—I think that generally it would not be useful to go over five minutes. Why should you not employ live steam? If your main engine stopped for five minutes, the steam generated in the boilers gets away unemployed by the safety valve.

Mr. Smoot—About two minutes is normal, is it not?

Mr. Battu—I think in rolling mills we have had to calculate on one to two minutes.

Mr. Cochrane—I understand that in the Bruay case the primary engine was about 200 H. P., and that the turbine was about 300 H. P. What was the size of the boilers used?

Mr. Battu—The set of boilers employed at Bruay give steam to a series of hoisting engines, fan engines, etc.; but I do not know why we should mention the power of said boilers, because we have nothing to do with them and their work. What we are after is to employ the steam exhausted from the engines. These main engines are perfectly independent of the Rateau system, and I will state here that one of the greatest advantages of this system is the non-interference with the main engines.

Mr. Hine—Have the plants that have already been installed shown any great results in saving?

Mr. Battu—I like to refer to the Bruay mines, because there the first application of this process was used, and because the plant has been running for nearly two and a half years. An entire plant of 200 electrical horse power of boilers, reciprocating engine, and direct current generator, has been replaced by the Rateau steam accumulator. This new plant, burning no coal, having a minimum of attendance, minimum of repairs, and of lubrication that is nearly negligible, has taken the place of the first plant that was shut down. It gives the current needed for the lighting of all the mines, and, further, gives the power used in driving two electrical fans. As you can see, the value of the economy at the Bruay mines can be easily figured: The cost of a ton of coal being about $2.00, the saving is in the tons of coal needed to produce the steam for a 300 electrical horse power plant, multiplied by $2.00, the value of the coal. May I mention that the steam accumulator needs no attendance, which certainly is not the case with a boiler. In this Bruay case, the weight of steam wasted is not very great. I have proposed an installation in this country where a slabbing mill and the auxiliaries exhausts into the atmosphere about 50,000 pounds of steam per hour. In my proposition I offer to put up a turbo-alternator of 1,600 electrical horse power at the terminals, the alternator having 50 cycles, 2 poles, 2,200 volts, at 1,500 revolutions per minute. The vacuum which I propose, and which has been guaranteed to me by an American constructor, is of 28 inches, and the auxiliaries will certainly not use over 2 per cent of the power generated. I think that a proposition of this sort speaks for itself.

Mr. Tratman—It seems to me that the important feature of the system described by Mr. Battu is, that it provides for utilizing steam that ordinarily goes to waste. The steam is already generated, and every pound of steam generated represents an actual expenditure for fuel; but in the class of engines referred to, a large proportion of the steam is thrown away before it has done enough work to pay for itself. The conditions are such that it has been difficult to prevent this within reasonable limits of cost. But by the use of this turbine apparatus, the steam, after leaving the main engine, is caught and made to do a considerable amount of auxiliary work instead of being thrown away. It is simply a question of economical utilization of energy that is going to waste, with a resultant economy in operation.

Mr. Alvord—As I understand it, in a reciprocating engine whose work was constant you would not claim any aid by using the turbine in connection with the steam accumulator? In other words, what has been claimed is the regulation and utilization of intermittent or fluctuating exhaust?

Mr. Battu—Yes; if the flow of steam is steady, then you do not need to put in a steam accumulator to regulate it; the process is simply a method of employing an intermittent exhaust and transforming it into a constant flow, or constant enough to be regulated by the governor of the turbine.

Mr. Alvord I think some of us, in looking at the title of the paper, did not get that idea clearly in our minds: that the intermittency of the primary engine was the real feature through which this plant effected a saving.

Mr. B. W. Thurtell What does it cost to operate the auxiliaries?

Mr. Battu—Operating the auxiliaries maintaining the vacuum is essentially dependent on each particular case. The power generally used in normal conditions to maintain a good vacuum is that of ordinary condensation practice. The only thing tha tis desirable to obtain high efficiency is to have a high vacuum; no special effort has to be made, and many of the Rateau turbines are working on vacuums of 26 inches, the condenser being a simple ejecto-condenser. Once more, no special type of condenser is required with the process. The work is done by expanding steam from about atmospheric pressure to the vacuum of the condenser. Certainly, it is a great deal better to have a good vacuum, and a good vacuum obtained in normal conditions is always economical in connection with steam turbines.

Mr. Thurtell—Why is a high vacuum better?

Mr. Battu—I will refer the gentleman to my answer to someone preceding him on this subject.

Mr. Warder—The power we get out of a turbine is the difference of potential between the pressure of the atmosphere, say 15 pounds absolute, and of the steam at the condenser back pressure, say of 1 to 2 pounds. If we can increase the vacuum to 28 inches we are increasing the utilizable power, but we are increasing the initial cost and the cost of running the condenser. The relative cost of the power to be used, compared with the economical power, is something very hard to figure out.

Mr. Thurtell—The difference of potential between the turbine and the vacuum is not due to the pressure at all. It is due to the velocity of the steam flowing into the vacuum, and the reason that the engine runs after the intermittent steam is shut down is due to the fall of pressure on the other side.

I will say in this connection that I have just gone through a series of tests in connection with a plant where they told me they were getting something for nothing. They did not do it, however, for the cost of the plant and the operation of it, and the interest on the investment, made it a dead loss to operate it. If you can use exhaust steam at low pressure you have a high vacuum, otherwise you cannot get anything out of it. I want to know what the plant costs—whether it pays interest on the investment or not.

Mr. Battu—The gentleman states that the difference of potential between the turbine and the vacuum is not due to the pressure at all, and that it is only due to the velocity of the steam flowing into the vacuum. The velocity is dependent on the pressure, so I do not understand very well why the pressure has nothing to do with it.

As to obtaining something for nothing, may I tell the gentleman that we are very far from obtaining something for nothing in the system that has been presented. There is no fear that the efficiencies shown this evening are over the theoretical power obtainable in the steam after working in succession in both engines. Not knowing what plant has been mentioned, I cannot say, and would not care to say, what I think about it; but I see a parallel between the system I have presented and a supposed good-for-nothing plant, so I would like to express regret in not having been well understood and perhaps not believed by the gentleman. The economies I spoke about are enormously valuable if the figures I have shown are exact. I would suggest that the gentleman consult the various books written and papers read by eminent engineers, such as Mr. Hubert, Professor at Liège, Belgium, and Prof. Josse of Berlin, and to refer also to the test made by American engineers on the Bruay plant, and better still, to the book that has been published by the engineer in charge of the plant of the Bruay mines.

Mr. Thurtell—How large are the turbines?

Mr. Battu—I understand that Mr. Thurtell wishes to know what the difference in size is between two turbines of the same power employing different pressures of steam. The size of a turbine is far from increasing proportionally to the volume of steam that goes through it. The sections of the distributors have to be calculated and are wider with low pressures than with high pressures.

As to the obligation of having high or low vacuum, I beg the gentleman to be kind enough to refer to the table inserted in my paper.

This system has been investigated by the most distinguished mechanical engineers in America, and their conclusions have been such as to highly favor the Rateau system in some of their plants. No experiments are to be made actually. I had the honor of presenting to-night an actual industrial success. I certainly would not bring before this society the results of doubtful experiments.

Mr. Thurtell An engine that consumes 100 pounds of steam per horse power is not economical.

Mr. Battu I am not taking into consideration the efficiency of the prime mover. What I desire to employ is the exhaust of the engine.

As to the consumption of 100 pounds of steam per horse power of actual work done by a rolling-mill engine, non-condensing, the gentleman can inform himself and come easily to the conclusion that an average of 100 pounds of steam per horse power is not uncommon.

Mr. Pearce—Does the efficiencies mentioned take into consideration the condensation in the piping and cylinder?

Mr. Battu—No; when I say that with 31.7 pounds of steam we obtain in said conditions one horse power electric at the terminals, I mean that the turbine must receive those 31.7 pounds.

Mr. Pearce—In other words, you gain the work done by the secondary engine?

Mr. Battu—Yes.

Mr. Watkins—What does it cost per horse power to install the accumulators?

Mr. Battu—This question tempts me to take up the commercial part of the subject, but I will resist the temptation, because the Western Society of Engineers desires only the scientific presentation of the subject, and I am certainly not appearing before this society for the purpose of taking up the matter from a commercial standpoint. The commercial proposition is the most brilliant part of this invention. The price of turbo-generators, condensers and steam accumulators can be easily calculated. My reply would be, then, on the amount of royalty the inventor would ask. May my silence be excused on this matter. It is easy to see that the steam accumulator is less expensive than boilers of the same output, and turbo-generators are less expensive than generators and reciprocating engines. A special combination on which we have contracted in Germany may enlighten you on the value of the economy obtained by the Rateau system. A steel works has asked for an application for utilizing the exhaust of a rolling mill. We have agreed to put in all the apparatus, steam accumulator, turbo-alternator and condenser, and to sell the kilowatt hour at a price that will often be less than the actual cost of production with boilers and generators. After selling the electric power for eighteen months we agree to be satisfied, and we claim to be paid back for all the installation and royalties. In fact, we can say that this special installation pays for itself in eighteen months, after which the steel works mentioned have the entire installation and the benefit for nothing.

Mr. Thurtell—Does it not require an immense turbine to utilize steam in that way?

Mr. Battu—No, not at all; the engines are remarkably small. As I have already said, the size of the turbine is not proportional to the quantity of steam employed. The size of the distributors is enlarged and suitably fitted.

Mr. Thurtell—Would it not be just as well to take a lot of "nigger heads," or boulders, and put them in the accumulator to absorb the heat from the exhaust steam of the primary or high pressure engine?

Mr. Battu—Yes, any scrap metal can be employed; but you must not lose view of the fact that the surface in contact with the steam ought to be as great as possible, on account of rapid exchange of temperatures.

Mr. Pearce—Suppose that a compound or triple expansion engine is employed, using 25 pounds of steam, perhaps (I do not think that is at all uncommon). In a case of that kind, what would be the value of the system you suggest?

Mr. Battu—The value of the primary engine is quite independent of the steam accumulator. If you have a very perfect primary motor, it is all right; the exhaust can be regularized and employed by a steam accumulator. I do not know of non-condensing hoisting engines that use only 20 pounds of steam per useful horse power.

Mr. Pearce—I am speaking of compound or triple expansion engines.

Mr. Cattu—I am speaking of any engine running with great and incessant variations in load.

Mr. Pearce—Suppose you have 100 pounds of steam. Would you utilize 80 per cent in your turbine?

Mr. Cattu—It all depends on the condensation in the cylinders and in the piping. In other words, 20 per cent of condensation is an hypothesis, and I think it very generous.

Mr. Hine—Without reference to what the economy of your engines is—whether 20 pounds or 80 pounds—if there is, for example, 50,000 pounds of steam going to waste, the Rateau system will employ 80 per cent of it, if the condensation in the pipes is 20 per cent. Is that it?

Mr. Cattu—Yes.

Mr. Tucker—Would not a steam accumulator interposed between a central condenser and the engines exhausting intermittently give a very satisfactory result in the way of obtaining a steady vacuum?

Mr. Battu Yes. As I have stated, this application has already been employed successfully, but, as shown in this paper, the advantage of employing the remaining power of the steam in a turbine before condensing is far more advantageous than the direct condensing of intermittent running engines.

Mr. Almert—In the case of a central station lighting plant, where engines run 24 hours per day and where the engines are fairly constant, this system has no place, as I understand it.

Mr. Battu—No. The steam economy of continuous running engines of this class, when properly condensing, has very nearly reached the maximum of utilization of steam that can be expected. I do not see how you can think of employing a system that has for its object to regularize a flow of steam when that flow of steam is already constant.

Mr. W. H. Pearce (by letter)—Some of the questions that have been asked are at least very plain, others have seemed to carry with them the inference that an impossibility existed of accomplishing the results which the author of the paper has placed before us. It seems to me that these questions should not be asked unless a sufficient foundation for them exists. Personally, I am very much interested in the utilization of exhaust steam for any purpose. I am not familar with the details of the apparatus as presented to us this evening, but upon the face of the evidence presented, I think we should congratulate the author upon his success, as his proposition has met with no substantial contradiction, and I fully believe the results that he states can be and are accomplished.

One of the gentlemen present has asked if this system has been placed in operation in this country. This would seem to infer a doubt as to the possibilities, as though the questioner would not believe the statements made unless he saw the apparatus in operation himself. This is a position that many engineers take on questions that are new. I maintain, however, that it is entirely wrong. Never would any improvements be accomplished if success must depend on the thing being done before it could be believed. Engineers should judge of the feasibility of a proposition from the engineering facts presented to them. As the proposition presented by the author of the paper under discussion seems to me as being perfectly feasible, and that offers a substantial means of utilizing a large portion of the heat of the coal that has heretofore been wasted in the exhaust from steam engines, I wish to congratulate him on so sound a proposition.

CONTEMPORARY TECHNICAL EDUCATION.*

John R. Freeman, V.-P. Am. Soc. Mech. Eng.

Mr. President—As delegate on behalf of our Engineering Societies, I must explain that these are also Schools of Applied Science. They are the more attractive to students since they hold no examinations; all studies are elective and voluntary; one recites only when he feels like it; and the social element is pre-eminent.

Into this university of the Engineering Societies, we hope to receive all of your graduates and to retain them as fellow-students and warm friends for all of their lives.

APPRECIATION OF THE TECHNICAL SCHOOL.

In speaking on behalf of the engineering profession, my first words must acknowledge our great debt to the technical school and that debt is increasing from year to year. Our members are coming to be recruited in an ever-increasing proportion from the technical graduates. (1)

From the researches conducted in your laboratories, we obtain much of our most valuable engineering data.

Our best books of reference for the practicing engineer are nearly all prepared by the professors in these technical schools. (2)

The strongest foundation for a country's future industrial and commercial welfare is to be found in Schools of Applied Science, well equipped, guided by men of broad mental horizon. This is scantily appreciated as yet by the mass of strenuous Americans, but it has long been clearly seen by the Germans, and is beginning to be seen by the English. (3)

The cost of duplicating the land, buildings, equipment and endowment of the largest and most complete technical school in the United States is little more than half the cost of one of the latest battleships, and the running expenses of the largest technical school per year are about the same as those of a battleship. (4) The technical school has a use no less important than the battleship in the "first line of national defense." The time has already come when the commonwealth and the nation should contribute more liberally to the burden of its support and help it to ever broader

*An address at Cleveland, O., May 11, 1904, at the "Case School of Applied Science" at the inauguration of President Chas. S. How. See Journal, June, 1903, Vol. ix, p. 339.

usefulness. With the increasing numbers of students and with the rapidly increasing cost of laboratory facilities needed for the best training, the need of funds is greater than private munificence can be relied upon to meet. The demonstration of their great value to the prosperity of the state is already complete.(5)

In the reawakening of the old spirit of commercial adventure in foreign lands, we must to-day base our hope of success on superior excellence and economy of manufacture and in the calling of our engineers to foreign lands.

The growth of our cities is laying a burden of new and larger problems on our departments of public works, a burden which only those trained in the Schools of Applied Science can carry wisely and well.

The business man, when he comes to see these matters clearly, will urge again and again a generous support to Schools of Applied Science by city, state and nation when private munificence falls short.

These schools need, as managers, the strongest men that can be found, the men of broadest horizon, the men that arouse the noble ambitions of young men toward advancing the state of an art and that can impart the spirit of joy in work.

APPRECIATION OF THE TECHNICAL GRADUATE.

For twenty-five years I have been observing the increasing respect paid by our industrial leaders to the training gained in the technical school. The technical graduate himself has come to better understand his own limitations, and his need of a course outside, under instruction from the foreman and the mechanic. The man of business is coming to understand that there are "firsts," "seconds" and "thirds" produced, that some excel in judgment and some in skill, and that it is not the mere fact of being a technical graduate that brings success, but that given inborn executive ability, the training of college or technical school gives to its graduate a tremenduous advantage over the man of equal native force who has not this training.

Twenty-eight years ago the finding of openings by my own fellow graduates was difficult and slow—not a third of our men found openings of fair promise within the first six months; the average "captain of industry" did not then know just what a technical graduate was, or what he was good for.

We then listened to prophecies that the annual output of engineering graduates would soon overstock the market. To-day, notwithstanding that, during the past quarter of a century, technical schools have multiplied on every side and that classes in many of the older ones have increased fourfold, the output is quickly absorbed. The department head in one of our largest technical schools has applications from managers of important works for double the number of his graduates, and it is said that certain large and progressive concerns send an agent around the schools in January to select from the brightest of those who are to graduate in June.

The mere register of the occupation of the graduates from any leading School of Applied Science is a most eloquent commentary on the commanding influence of these schools.

Twenty-five years ago, among managers of works, I heard much about the good *practical* man and his superiority to the theoretical college graduate; to-day it is coming to be generally recognized that the *good* practical man is the one who has graduated from a technical school and who has then been seasoned by a few years of experience in bumping against corners of construction, and the technical graduate of proved business ability is in special demand.

The Technical School, the School of Mechanic Arts, and the Mechanics' Correspondence School, each has its special and distinct value in our industrial life. We should make the technical school attractive to the brightest minds, and should look to it for our industrial and commercial leaders and for the best custodians of the public health, of our water supplies and other public works.

In order to get the most out of the existing technical schools, let us keep in mind the limitations within which they can do their most efficient work, and the fact that not every kind of work will be best done by a technical graduate. The students found without promise of final success should in all kindness be allowed to depart and not hold back the best.

Doubtless a man may give lines and grades as well, may drive an engine or detail steel work better, if his four years of early manhood have been spent gaining this dexterity and skill outside the technical school. The late Col. T. J. Borden, a sympathetic, thoughtful man of 40 years' experience as manager of large industrial works, and himself a technical graduate, told me that for many years he had been observing that a faithful, uneducated laborer would in general keep a more correct tally sheet of the unloading of a cargo than the bright high-school graduate whose thoughts were flying off to other things; that a large factory engine would be run with better attention and fewer breakdowns by a graduated stoker or oiler than by an expert machinist, who was liable to be scheming out improvements and to have his mind busy with something other than the mere operation of this machine; that often the best routine work was done by a man who was not capable of anything very much better.

The young man who is to follow a narrow routine through life will not have added much to his efficiency, as a machinist, by the long elaborate course of the technical school. For those constitutionally deficient in ambition, or for those unfortunates who can never comprehend the art of getting on in the world, these four extra years are ill spent at school, but there are plenty of young men for whom this training of the technical school is the best possible training, and there is plenty of opportunity for a larger number of these men than all of our present schools can graduate.

Men cannot be shaped on the interchangeable system of the American machine shop, each will be a "special," and, as already remarked, there will be produced "firsts," "seconds," and "thirds," but fortunately the demand for all types and grades exceeds the possible supply for years to come.

Among the graduates some will possess that rare faculty for which "initiative" is the phrase of the day, and among these there will be some who will possess that quality of balance and judgment, and attain such knowledge of men, that they will become great leaders, the captains, will establish their own industrial works or be called to the $10,000 positions which are always so hard to fill right. Others, without this business insight, but perhaps more learned and more skillful in engineering, will design machines and bridges, supervise factories, become the lieutenants and fill the $4,000 and $2,000 positions, and still a larger number will do noble work as the sergeants, corporals and privates and be made better men by the broadening of their minds.

The training of no school can make the square peg fit easy in the round hole, and, out of a hundred boys, but few are born with the ear of a musician or the eye of an artist, or with the observing, inquiring, ingenious, imaginative mind, which schools can stimulate but cannot create, and without which conspicuous success in constructive engineering is impossible. But for the young man so fitted by nature, a technical school of broad scope and high aim is a royal road.

A ROYAL ROAD.

The old statement that "There is no royal road to learning" is untrue. The man of affairs has come to understand that *the technical school is a royal road to learning*, a shorter road, an easier road, through a more beautiful landscape, and in equal time attaining a broader outlook.

A man with the earnestness and patience of John Brashier, the strong purpose of John C. Hoadley, the rugged common sense of Edwin Reynolds, the strong, kindly heart and quick intelligence of

John Fritz, or the genius of Edison, may reach an equal height by a longer and more arduous road, and, like the athlete, increase his strength and harden his endurance in the greater effort, but the royal road of the technical school, in its four years, may, from its small group, gathered part by chance and part by process of natural selection from more than ten thousand school boys, bring perhaps ten to the point that otherwise not more than one or two or three could hope to reach in twice these four years.

The technical school is not exclusively for the brilliant man. Much of the world's best work is done by the man of slow-moving intellect, to whom the good Lord has given the greater treasure of persistence, of steadfastness, with enough of imagination to feel what is concealed within the cloud on yonder difficult and distant hill.

There is danger in relying upon lectures and reading for teaching, and upon written examinations for measuring up a student and his fitness to continue on his four years' course. One of the greatest advantages of the technical school is found in its laboratory method, for the reason that the personal, individual contact with the student daily in the laboratory gives an opportunity for helping the one who is slow to develop himself.

I have had perhaps twenty graduates tell me in familiar talk that the most helpful man to them of all the "Technology" professors was the lamented Holman. Why? First, because he was intellectually great and a noble man, and second, because he took pains to get acquainted with them and their individual needs *in the laboratory.* The ablest professors should be brought into earliest possible contact with the freshmen in the laboratory.

THE OPPORTUNITY FOR THE TECHNICAL GRADUATE.

For a few moments past we have been considering the broader appreciation, by men of affairs, for the work of the technical school; let us for a moment review the causes of its great opportunity.

That the manufacture of power was the mainspring of the onward movement of the nineteenth century was made plain, perhaps more lucidly than ever before, by that great engineer, whose recent loss we mourn, George S. Morison, in his Phi Beta Kappa address at Harvard in 1895.

In the skillful application of manufactured power lies the great opportunity of the engineer.

The distribution and use of manufactured power are increasing by leaps and bounds in a way that few of us can see in perspective.

It moves a thousand cotton spindles guided by a single hand; with the power of a thousand horses, it(6) draws your twentieth century express; large cotton factories in Montreal are driven by a waterfall nearly a hundred miles away; the power of Niagara rends the strongest chemical affinities. The chariot, as made in Cleveland, is horseless, but it is propelled by the power of twenty-four horses, all generated in a little space and derived from a harnessed explosion. In another part of your city, the most delicate and accurate engraving that the skill of the world has known, an astronomer's circle with markings correct within less than a second of arc, may go on in solitude as a result of a laborer shoveling coal under a steam boiler. Today there is far more steam power used in Lowell than water power, and in your city of Cleveland the power manufactured from coal far exceeds that of the greatest single development of water power in the world (7), Niagara not excepted. The General Electric Company had on its books on January 31, 1904, undelivered orders for steam turbines of an aggregate power of 350,000 horse power, an amount three times as great as the present total generation of power from Niagara and nearly half as great as the total water and steam power combined in the six New England states found in the census of 1880.

With the aid of unlimited power work is performed in a larger way and with greater rush, and with this comes the greater need of executive ability, of captains and corporals of systematic, observing habit, equipped with the tools and training of the technical school.

This is a transition period, and never was there such opportunity for the trained engineer. Mechanical production must supply the natural increase due to the growth in population, and replace machines worn out by service, and even new machines by something newer. Here in Cleveland your horse cars were not worn out when the cable car replaced them, your cable railways were not worn out when the electric car came in. Not only the equipment, but the shop that makes it, must largely go into scrap.

Two or three years ago one of the leading engine builders of the world began on new shops in a city on the Great Lakes, the largest of their kind, designed for building engines of the most massive type. Hundreds of thousands of dollars were expended on these shops and their heavy machine tools, but before these shops were occupied, customers were inquiring, not for engines but for steam turbines.

The leading pump builder of America began two years ago on new shops near New York, these also to be the largest in the world; the plans had been matured by years of study for building pumping engines of the ordinary reciprocating type. Before these shops are ready for occupancy the old and simple and inefficient type of centrifugal pump is suddenly so improved as to threaten a revolution which may profoundly change the type of shop equipment demanded.

A maker of valves and fittings, a concern which has kept steadily up-to-date for more than a quarter of a century, started, about two years ago, to supply its expanding trade by a factory on the shores of Long Island Sound, designed to employ at first 2,000 and later 4,000 men. The plans were matured with rare care and judgment.

First, their man of greatest skill in shop methods plans for his various machines and lays out his floor space. Next, the skilled mill engineer makes plans to house that floor space in. Next, an architect, of national reputation for his inborn sense of beautiful form and graceful line, models the outlines of exterior wall and windows and roof. Machine tools of latest design had been purchased, apparently everything had been provided for, when, just as the roofs are on, the successful demonstration of a new kind of tool steel, which permits of far deeper and more rapid cuts, calls a halt and requires a radical change.

All this is recent and the end is not in sight. Seventy-five years ago, when Cleveland was a frontier village, within the memory of a few men now living, the dry dock in the Boston navy yard was the most monumental piece of engineering construction and the greatest single work of internal improvement yet completed within the United States, and the total of manufactured power in the United States did not equal the output of one large power station of to-day.

It is only forty years since the first distinctive School of Applied Science, or Institute of Techology in this country began, after years of patient explanation and pleading by that lovable, eloquent, prophetic, noble man of science, William Barton Rogers, and how profoundly it has influenced the whole course of higher education.

Although the lines of work formerly recognized as engineering may be crowded, there are, on every side, unworked fields in which the trained engineer, possessing business ability, be he builder, sanitarian, chemist, mechanic, or electrician, can introduce system, discover causes, lessen cost and improve the product and find for himself a competency and joy in work.

A PLEA FOR BREADTH OF CULTURE IN THE SCHOOL.

The other speakers to-day are presidents of colleges, educators of wide experience and national reputation, and it savors of rashness for me, in their presence, to venture opinions upon the aims and methods of a technical school, but during my twenty-five years of taking on several technical graduates in almost every year, and trying, through them, to keep in touch with the schools, I have so often found what has seemed to me a misapprehension among students, friends and patrons of technical schools, that, to an audience of friends and patrons, a few words from the standpoint of a business man and practicing engineer, may have some interest.

Why do we not find the greatest prizes of the industrial works and of civic administration going *more* often to the technical graduate? The commercial department pays a better salary than the engineering department. We have all seen plenty of examples to prove that technical training is of itself an aid rather than a bar to commercial success.

Have our men got too narrow a training in the technical school?

Within the past week I have chanced to hear two heads of concerns, employing many scientific men, say in substance that the old academic education fits better for the position where one deals with men, or for the $10,000 position, while the technical school fits better for the position that deals with materials, or for the $4,000 position, and I note that sons of my old classmates are being sent first to Harvard or Yale or Dartmouth for *four* years and then to "Technology" for a *two* year's course in science.

Six years time, from 18 to 24, is more than the average young man can afford to spend at school. It brings him into the works too late. When we more fully appreciate that education, rather than information, is the true aim of the technical school, then a broad education and sufficient information can both be given in a four years' course.

Can we not give a better education to the great majority of our students and plant in them thirst for information, by doing fewer things more profoundly and putting more emphasis on the personal element?

Is not one great captain of science or industry, like Pasteur, Kelvin, Ericsson, Bessemer, Westinghouse, Brush, Mills or Alex. Brown and a hundred others, worth more to his country and his neighborhood than a room-full of the very necessary and useful sergeants and corporals of science and industry?

Cannot our school do the most good and best serve all, and best stimulate the ambition of all, by trying to fit men for the position of captain; and if the man, skilled in the application of science, has also executive skill and such knowledge of men that he can negotiate, convince and arouse men, will he not have a wider opportunity to do good and to advance the state of the art and the public welfare; and shall we not, by addressing our teaching to the highest grade, thus produce more of the $10,000 men and at the same time better $4,000 men?

In separating students into many courses, is there not danger of splitting things too fine? Have the schools not already gone too far in specializing for the undergraduate?

It is a matter of slight importance to the builder of machines or of water works whether he takes the course in mechanical engineering, civil engineering, or general physics, if he is fortunate in his teacher.

The chief function of the technical school is not the filling of a man's memory with formulas and with knowledge of how everything is made, but rather is the training in methods of thoughtful research, of teaching how to put the question and where to find the answer, of how to set traps for our own unconscious errors, how to save time by understanding just what degree of precision is necessary to the case in hand, how to measure with certainty the limits of the ever-present error, and above all to develop and strengthen a warm, enthusiastic, undeviating love for the truth.

In my own college days, I did not have it made plain, and I failed to grasp the fact, that perhaps the greatest opportunity of college life is that of coming to better know one's fellow-men, and it is in failure to appreciate this more than in any other one feature, that the professional school has failed in comparison with the older colleges. In the protest against the old education, exemplified in the early development of the Massachusetts Institute of Technology and other similar schools, the pendulum swung beyond the centre, and the value of the social idea was not for a time appreciated. To many of us there was lost the inspiration and broadening, the deeper understanding of humanity that may come from entering into the daily life of the ancient civilizations enough to understand that human nature is much the same through 3,000 years. We missed that focussing and sharpening of the wits which comes from taking time for the discussion of current events with our fellows.

We had a professor who wisely read to his class those verses on The Deacon's Masterpiece, "that was built in such a logical way," as typifying the ideal machine. McAndrews' hymn may teach a deeper lesson. The man should be led to find inspiration in his machinery, while in the technical school.

A few weeks ago, in Chicago, I sat beside a classmate, a former "grind," now a successful man of business, at a gathering of the graduates of one of our largest technical schools. Said he, "We were brought up wrong in being taught to spend so much time on our studies; we practiced a false economy in being too thrifty in our early years." We were too late in learning that opportunity, sustaining power and a stimulus toward success, came more from a wise good-fellowship than from a high scholarship, and that the art of being what in your terse Western phrase is called a "good mixer" was an art well worth time, money and paternal advice to cultivate. It is by giving the technical graduate a wise start in this direction that he will ultimately come more often into the larger opportunity and the higher salary of the commercial end.

This social feature is, in the final analysis, the chief value of the engineering societies. Although papers are presented in which one engineer so presents his experience that a hundred others may find each his own course more clear in attacking a similar problem, although one may hear presented in an evening hour the results of experiments and research that have cost a year of toil, all so summed up in a few lines of formulas or constants that a repetition of this labor and expense is saved to all who follow, and although the master mind may publish in the transaction a study upon difficult and disputed points that will lighten labor or save mistakes to many of his fellows, yet, after all, the preeminent usefulness of the Society of Engineers is in the bringing of men into personal relation, inspiring the young man by personal contact with the man who has done things, giving the older men a chance to size up the growing young men; and, among equals, it removes the bitterness to personally know our successful competitor and to know that he is a good, honest man.

If it be asked what suggestions can be offered to his friend, the teacher, by a practicing engineer, who has for twenty-five years enjoyed taking "green graduates" and trying to help them on their post-graduate course, I venture the following:

Dwell on the principles of research, fill the student mind with a comprehension that the school is not so much for filling his memory with information as for teaching the scientific method.

Give more attention to the principles of writing reports in clear, exact and vigorous English, to measuring the exact meaning into every sentence. Teach what may be called "Commercial rhetoric," bringing the result quickly into the view of the busy man and seeking to so arouse his interest in the opening paragraphs that he will continue reading instead of laying it aside for the leisure hours that may never come.

Emphasize the need, in the practical world, of "getting there" on time.

Recognize that a judicious "cramming for examination" is legitimate, and that how to do it with the least internal friction is a most worthy subject of instruction. In closing business contracts and in expert work, it is a much practiced and most useful art.

Direct attention to the conditions necessary for obtaining a maximum output from the human machine. How seldom a man gives to his own body the same care he would give to that of a $1,000 horse? Long hours under stress in emergency are easy if the man knows how to avoid fatigue through variety, and has the will power to practice what he knows.

Probably there is no better way to save time and cultivate judgment than by practice in quick estimates between limits. What does that stone weigh? Not more than 6 tons, not less than 4. What will that casting cost? Not less than $50, not more than $100. If the owner asks the cost of repairing the tangled smash-up of ten minutes ago, the young engineer can give him almost instantly an estimate that may serve his purpose, and be correct, if he states it between limits, as, "not more than $10,000, and not less than $1,000." Twenty-four hours later he may be able to state it as not more than $5,000 and not less than $4,000.

Urge upon your colleagues the fact that they owe it to their fellow-citizens and to the loyal intelligent public that supports the school, to promptly and continually translate the story of the latest discovery of obstruse science down to the understanding of the well-educated non-technical man.

Stimulate the interest of the students by continually bringing before them the results of the latest research and of what is being found out in other departments of the school.

Recognize the fact that these four years of time, with their attendant expense, are too valuable to be devoted to the attainment of mere manual dexterity. This can be more cheaply learned in the field or workshop than in the school. Do not shrink from turning out graduates who will be strong on theory, while perhaps weak on practice. They can get their practice outside after graduation, and perhaps under the quickening influence of some short-lived ridicule by the routine workman. The sound foundation of mathematics, the facility in handling and transforming difficult equations, the mental grasp of difficult considerations, so as to state them in the language of mathematics and quantity, must be acquired in the Technical School or the chances are they will never be acquired.

Finally, to the many students here, I can bring back no better word from out of the years since I left similar pleasant places, than to remind you how largely the success of a school depends on atmosphere and that every man has a share in forming public opinion; and to urge you to fill the student atmosphere with the fraternal spirit and with ideality—ideality! with the love of thoroughness and with reverence for character.

NOTES.

(1). Out of the latest 1,000 candidates for admission to the American Society of Civil Engineers in the three grades, member, associate member and junior, about 75 per cent have graduated from a techinal school; in the American Society of Mechanical Engineers this proportion is 60 per cent; in the Electrical Engineers, 44 per per cent; in each society the proportion is largest among the junior members.

(2). Out of a catalogue of 55 technical books brought out by a leading American publisher of engineering books during the past year, 75 per cent of the whole were by professors, mainly in technical schools.

(3). See presidential address of Sir Norman Lockyer, president of the British Association for the Advancement of Science, in September last, entitied "The Influence of Brain Power in History," devoted to urging the British nation to come to the support of its technical schools.

(4). COST OF A BATTLESHIP.

The approximate cost of the hull of a first-class battleship is	$3,250,000
The engines, machinery and engineering stores cost about	1,300,000
For the largest ships the cost of armor is about	1,750,000
Of armament about	1,050,000
The supplies and general equipment about	100,000
Total cost of a first-class battleship about	$7,450,000
For a ship of the Vermont class of 16,000 tons displacement, with the latest armament and including designs and superintendence, the total cost may approximate	$8,000,000

The cost of maintaining such a ship in commission will be nearly 50 per cent more than for the three ships as stated below, which are of 12,000 tons.

The report of the Secretary of the Navy shows that the cost of maintaining the three battleships, Alabama, Kearsarge and Wisconsin, in commission for the year ending June 30, 1902, averaged	$ 441,248
Current repairs	30,914
Total	$ 472,162
The foregoing includes pay of officers, crew and marines, and cost of stores, including coal, but includes no allowance for depreciation. If depreciation be figured at the moderate rate of 5 per cent annually, having regard to wear, and to improvements rendering much obsolete, this adds nearly per year	400,000
	$ 872,162

COST OF A TECHNICAL SCHOOL.

Several of the leading schools of applied science are parts of great universities in which the accounts or different departments are so merged that it is difficult to separate the cost of plant and running expenses required for the technical courses.

The Massachusetts Institute of Technology is perhaps the most convenient example for present purposes, because of being almost exclusively a technical school. Its present site is on land of exceptionally high value for business purposes because of surrounding developments; therefore I will not include the full sum for which this land could probably be sold.

It is estimated that a suitable sight could be procured for	$ 250,000
The estimated cost of replacing present buildings at present price is	1,044,000
The total value of apparatus and furnishings, as estimated for insurance purposes is	386,000
Approximate cost of duplicating plant	1,680,000
The endowment or stock, bonds and real estate producing direct income is about	1,150,000
Total	$2,830,000

The number of students is 1528.

The annual expenditure last year in round numbers was as follows:

Salaries	$ 320,000
Fuel	25,000
Water, gas and electricity	7,600
Repairs	16,000
Printing lecture notes, catalogues, etc	14,000
Laboratory supplies and libraries	50,000
General supplies and maintenance	30,000
Miscellaneous	13,000
Total	$ 475,000

This amounts to an actual expenditure of about per student (including special students, some of whom take few studies and pay less than full fee)	$ 311
Reckoning the interest at 4 per cent and depreciation on whole plant, buildings and furnishings at 5 per cent per annum, this adds about	91
Making the total yearly cost per student, of which he pays a tuition of $250	$ 402

(5). The generous support given by Michigan, Wisconsin and California to their great state universities, which are coming to be in large proportion schools of applied science, may indicate a better appreciation of this service to the state than is yet found in the legislatures of our eastern commonwealths, or than is yet disseminated through the mass of their intelligent citizens.

In 1903 Michigan paid from the state treasury for the support of the state university	$559,835.03
Wisconsin paid	293,583.00
The University of California has an income for current expenses for 1904-5 (of which sum nearly one-third is appropriated for departments in which engineering students predominate) of	659,808.96

(6). A locomotive engine of the type used in drawing the Twentieth Century over the New York Central portion of the route has, under test, shown a continuous development of upward of 1200 horse power at speeds of from 40 to 57 miles per hour.

From a large type of locomotive, recently put in service on the New York Central & Hudson River Railroad, an indicated horse power of approximately 2,000 has been obtained.

On the Lake Shore road, indicator cards, taken from fast passenger trains at one minute intervals for an entire trip where the speed over an entire division averaged about the same as for the Twentieth Century express, namely 54 miles an hour, showed an average of 1,000 horse power for the entire division. For dsstances of 5 to 10 miles, powers as high as 1,500 to 1,600 horse power has been obtained.

(7). The amount of water power now in use daily by the works located at Niagara is not far from	75,000	H. P.
In addition to this, there are now generated at Niagara, and transmitted to Buffalo and other points, not far from	25,000	"
The aggregate capacity of the generators installed up to date at Niagara is about	130,000	"

On the American side an additional capacity is being provided of perhaps	50,000	"
And on the Canadian side the contracts have been let for machines capable of generating about	80,000	"
In the city of Cleveland an approximate estimate, reasonably made up by Mr. Ambrose Swasey and Mr. Scoville, vice-president of the Cleveland Electric Illuminating Company, puts it (for the total of the large electric power and electric railroad plants) at.	50,000	"
At the 73 large factories in Cleveland they estimate the power used as	85,000	"
In small factories, lumber yards, office buildings, etc., probably....	25,000	"
Total	520,000	"

SOME NOTES ON THE EDISON NICKEL-IRON STORAGE BATTERY.

BY F. M. DAVIS, M. W. S. E.

Presented before the Electrical Section Oct. 14, 1904.

Being one of the newer members of the society, the speaker was somewhat surprised at being assigned to a paper for this, the opening Fall meeting of the Electrical Section. However, it is a pleasure to address you on a subject that should appeal to the interest of all persons connected with the electrical profession, especially those interested in portable battery traction work or having to do with small isolated storage battery equipments, in which latter case, expert attendance is often too much neglected when trouble arises. Such considerations as these have led to the development of a new type of storage battery.

The new Edison storage cell, having only recently been placed on the market, has been subject to some question concerning the remarkable claims made for it by its manufacturers. Hence, certain tests were made, the object of which was to determine these claims and moreover to manipulate the cell under various conditions sufficient to furnish data for a thorough working knowledge of the behavior of this cell in practical operation.

The chief points to demand attention are durability and stability, ampere hour and watt efficiencies, charging and discharge rates, internal resistance, voltage, maintenance, etc., as indicated under the several topic headings that follow.

The Edison storage cells now on the market are classified under three sizes, as shown in the following table:

TABLE OF EDISON CELLS AS LISTED.

Type of Cell.	E-18	E-27	E-45
Capacity in ampere hours..................	105 to 115	160 to 175	260-280
Average discharge voltage per cell...........	1.23	1.23	1.23
Rates of discharge in amperes........... ...	30	45	75
Satisfactory rates of charging in amperes....	40	65	100
Suitable times of charging in hours.........	3¾	3¾	3¾
Weights in pounds per cell, complete........	13	17½	28
Price.......	$10.00	$15.00	$25.00

The cell used for this test was an E-18, the smallest size. It is assumed that the general characteristics of this cell hold true for all Edison cells of this general type, including all sizes. The mechanical construction of the cell is indicated in the following general description:

This cell consists of a steel case containing the plates and electrolyte. The protecting case or retaining jar consists of a thin, slightly corrugated and thoroughly nickel-plated steel envelope of rectangular shape.

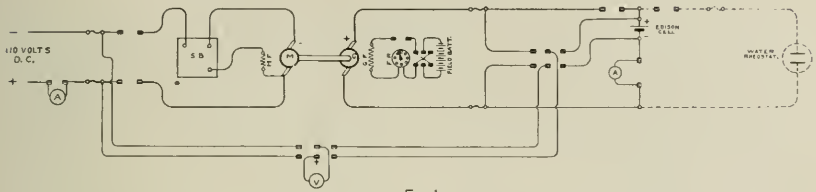
The element of this cell consists of twelve positive plates containing oxide of nickel associated with six negative plates containing oxide of iron. These plates are made up of steel frames or grids, in which are fastened a large number of small pockets containing the granular metallic oxide.

The pockets for retaining the oxide are of very thin steel, perforated with fine narrow slits for enabling the electrolyte to gain free access to the oxide during all processes of electrical activity. These pockets are so designed that when placed in the steel frames and subjected to pressure, the edge becomes crimped or locked into the frame of the plate, thus insuring permanent and rigid construction.

Nickel oxide is used for the positive plates and iron oxide for the negative plates. These oxides are prepared in a finely divided state by special processes devised for this purpose. It is claimed that they are absolutely insoluble in the electrolyte, and retain their granular state sufficiently to prevent their passage through the pores in the pocket walls, as would occur if they underwent disintegration. This claim is shown to be well founded, by the fact that the cell lost no appreciable capacity in the first seventeen charges conducted upon it, and by the absence of any appreciable amount of sediment in the electrolyte after the test was completed. These oxides are of a very similar appearance in texture and color, but their chemical affinities and equivalent weights are different; hence, the adaptability of the one for the positive electrode, and the other for the negative electrode.

The positive and negative plates are arranged alternately, the positive in pairs and the negative singly, and are separated by means of thin hard rubber insulators. They are also insulated from the case by means of hard rubber. Similar plates are connected by a bolt which, holding the plate contacts firmly together, insures good electrical contact. Two terminal posts are provided. These are connected one to each set of plates from which they extend upward through hard rubber bushings to the outside of the case. After the elements are in place, the cover is sealed on by means of a special soldering process. Certain other details will be explained in comparing this cell with the ordinary lead type of cells.

As the test must necessarily involve a large number of charges and discharges, it was necessary to devise suitable means of providing and controlling the necessary current. Different circuits were tried, until finally a very satisfactory arrangement was devised, as explained herewith, and illustrated in Fig. 1.



POWER CIRCUIT
USED IN TEST OF E18 EDISON CELL

Fig. 1.

In order to have an independent and flexible source of power a motor generator was provided. As a means to get the necessary regulation of voltage and current, the generator was reconnected for separate excitation from adjustable contacts on a storage battery. The final adjustment was attained by means of the field regulating rheostat.

By means of the motor generator set together with suitable switches and instruments, it was convenient to charge this cell at any desired rate within the current capacity of the generator, which latter, in fact, limited the maximum charging rate to 70 amperes on account of excessive heating in the commutator and armature.

It was at first attempted to control the discharge by means of an acidulated water rheostat, but the resistance of the various connections and wiring was so much in proportion to the low voltage of the cell that it was impracticable to attempt to attain sufficient range of control by this means. Several experiments were then tried and it was found that when the cell had been sufficiently charged and the generator allowed to slow down, with the cell still connected, the charging current also gradually diminished as the speed decreased, till at some point the current passed through zero and reversed. This discharge current came up to ten amperes as the armature came to rest. Then, in order to increase this discharge value, it was only necessary to start up the machine again, but with its field reversed so as to assist this discharge current. By means of the field regulator it was possible to adjust the output to any desired value, as in regular dynamo practice. This method served very well for all the ordinary tests, but the limited current capacity of the generator precluded its application for the highest rates required. For the higher rates, ranging from 75 to 150 amperes, a less convenient arrangement was adopted which served the purpose very well on the primary discharge, i. e., above one volt. The circuit for this high discharge was of very low resistance excepting that it contained two terminal posts about six inches apart, between which were stretched a number of turns of No. 22 bare copper wire in such a way that more or less strands could be applied by a simple process of winding turns off or on, as desired. This constituted a kind of multiple circuit hot wire rheostat.

In order to determine the effect of negative charging, such as would occur to any cell that chanced to be wrongly connected in any battery, it was merely necessary to continue the discharge through zero and then continue the current by means of gradually raising the voltage of the generator as the reverse E. M. F. builds up in the cell. In this way it is possible to obtain a complete cycle of voltage at a constant current rate, i. e., starting at zero, charge positively up to the maximum voltage and then, reversing the generator field, discharge down to and through zero, and so on negatively to the negative maximum when the generator field can be reversed to its original polarity and the negative charge removed, thus completing the cycle by bringing the charge back to zero again ready for a positive charge.

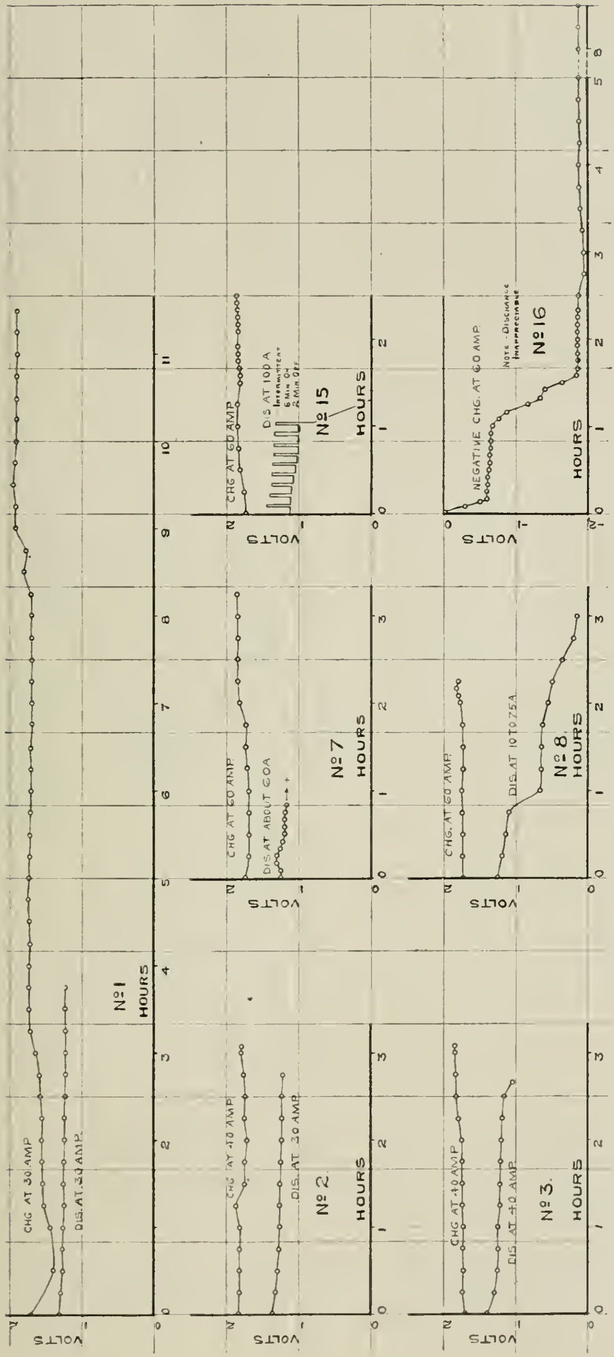
It was found that the negative charge was very small, practically negligible compared with the positive charge, and that the negative charging had little or no effect beyond bringing the cell to a state of zero charge after which a prolonged positive charging process was necessary, as in the case of the initial charge, to bring the cell up to its normal working condition again.

Only the general results and more important data will be incorporated in this paper, which, together with the drawings and curves plotted in connection herewith, are designed to present a clear insight into the nature of the subject investigated.

The greater part of the experimentally derived data pertaining to the cell is embodied in the curves of Figs. 2 to 3, where are shown the charge and discharge voltage curves of the several charges numbered directly in the order of observation. Comparison of efficiencies may be facilitated by reference to the efficiency table which follows the explanation of these curves.

Plot No. 1 shows the curves for the prolonged first or prelimi, nary charge and subsequent discharge. Up to the seventh charge- and in some of the subsequent charges, it was designed to instill only sufficient charge to insure a complete normal discharge. This condition appeared to be generally satisfied by about 12 per cent over charge at the normal 40 ampere rate and up to 60 or 70 amperes, beyond which a greater overcharge seemed necessary.

The low efficiency of No. 2 is ascribed to a possible incompleteness of discharge. This being followed by only a moderate charge would account for the exceptionally high efficiency of No. 3.



VOLTS
HOURS
CHG AT 30 AMP.
DIS. AT 30 AMP.
Nº 1
CHG AT 40 AMP.
DIS. AT 30 AMP.
Nº 2
CHG. AT 40 AMP.
DIS. AT 40 AMP.
Nº 3.
CHG AT 60 AMP.
DIS. AT ABOUT 60 A
Nº 7
CHG. AT 60 AMP.
DIS. AT 10 TO 75 A
Nº 8.
CHG AT 60 AMP.
DIS AT 100 A
INTERMITTENT
6 MIN ON
2 MIN OFF
Nº 15
NEGATIVE CHG. AT 60 AMP.
NOTE - DISCHARGE INAPPRECIABLE
Nº 16
0
1
2
3
4
5
6
7
8
9
10
11

FIG. 2.

The watt efficiency of No. 4 is low, because the discharge was carried to zero. The brief negative charge in connection with No. 4 is disregarded, as it appeared to have no effect. This inference is confirmed by No. 16 and No. 33, where the prolonged negative charges were found to have practically no effect. No. 5 charge was started at 80 amperes, but excessive heating of the generator armature required that the rate be cut down to 70 amperes. The low efficiency was due to the preliminary recovery charge following the previous complete discharge, and also to the high rate, it being found that the cell was more efficient at lower rates.

No. 6 shows high ampere hour efficiency and low watt efficiency, because the discharge was continued through both the primary and secondary discharges.

No. 7 was conducted for the purpose of finding the internal resistance of the cell at different degrees of discharge. The condenser method was used, as explained later. These readings were only approximate and somewhat irregular, on account of certain minor difficulties that were met.

No. 8 was conducted more accurately, but the time values are not all exact. In all cases the galvanometer deflections were of small range and of very brief duration, thus precluding absolute exactness in reading thereof.

Nos. 9, 10, 11, 12 and 13 are intended to show the relation between high and low current rates of activity. Nos. 9 and 10 show that the higher rates cause a greater difference between charge and discharge voltages, and hence lower watt efficiency.

No. 12, and also No. 3, show conclusively that a low rate is more efficient than a high rate. Nos. 11 and 13 show that the efficiency is the same, whether charged at a low rate and discharged at a high rate, or vice versa.

No. 14 was for the purpose of showing the effect of different current rates on the voltage. The results of this test are shown best on diagram Fig. 2. From the volt-ampere curve there shown, it is obvious that the voltage is inversely proportional to the current. It was found that the voltage drop caused by 160 amperes was only 32 per cent of the no-load voltage. The only evil effect of this high current rate appeared to be an excessive heating of the terminal posts. After the 160 ampere reading, the cell immediately recovered to 1.39 volts on 10 amperes discharge, which is only about 5½ per cent less than at the same rate before the higher rates of discharge were effected. This slight loss of voltage would be expected, as the voltage always gradually diminishes on discharge.

No. 15 shows an intermittent 100-ampere primary discharge, followed by a continued discharge at 60 amperes to zero volts.

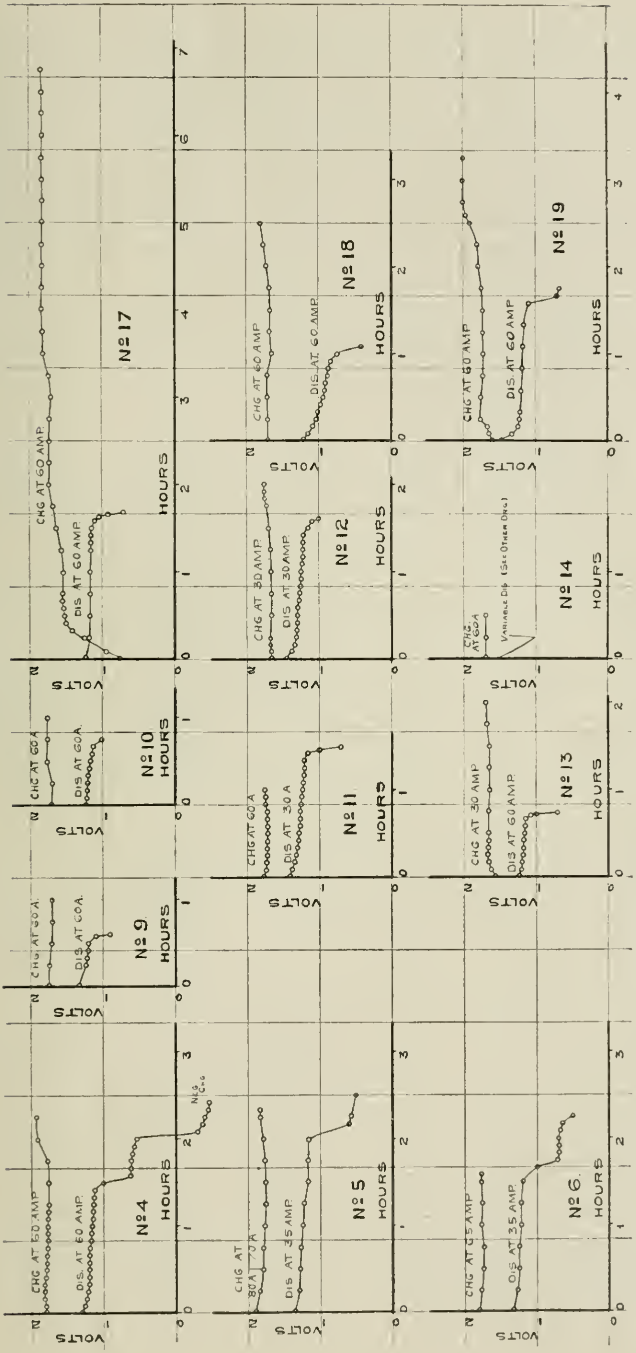

Nº 17
CHG AT 60 AMP.
DIS. AT 60 AMP.
Nº 18
CHG AT 60 AMP
DIS. AT 60 AMP
Nº 19
CHG AT 60 AMP
DIS. AT 60 AMP
Nº 10
CHG AT 60 A
DIS AT 60A.
Nº 12
CHG AT 30 AMP.
DIS AT 30 AMP.
Nº 14
CHG. AT 60 A
VARIABLE DIS. (SEE OTHER DWG.)
Nº 9
CHG AT 30 A.
DIS AT 60A.
Nº 11
CHG AT 60 A
DIS AT 30 A
Nº 13
CHG AT 30 AMP
DIS AT 60 AMP
Nº 4
CHG AT 60 AMP.
DIS. AT 60 AMP.
NEG CHG
Nº 5
CHG AT 80 A 70 A
DIS AT 35 AMP
Nº 6.
CHG AT 65 AMP
DIS. AT 35 AMP.
HOURS
VOLTS

FIG. 3.

Both the no-load and load voltages gradually fell away consistently in regular curves throughout the primary part of the discharge.

No. 16 was a negative-charging process, followed by an unsuccessful attempt to obtain a negative discharge. When being charged negatively, the Edison cell behaves very much like an ordinary counter E. M. F. lead cell, inasmuch as it will take up practically no charge, even though it presents an opposing voltage somewhat higher than the normal direct voltage. It is claimed by the manufacturers that the only effect of this negative or reverse charging is to reduce the iron of the negative plates to a very low oxide, which necessitates a subsequent prolonged positive overcharge to get the cell back to its normal working condition.

No. 17 counts for little more than a simple recovery charge in the positive direction.

No. 18 was a special test to show the effects of letting a cell stand fully charged with its electrolyte removed. It seemed at first to have suffered no injury beyond losing about 25 per cent of its ampere hour charge and 25 per cent of its mean discharge voltage; or, briefly, almost one-half of its watt hour charge.

The 19th charge was prolonged to a 77 per cent overcharge and was followed by nearly a normal discharge, indicating that the cell had suffered no appreciable injury by standing charged with the electrolyte removed, notwithstanding the evidence of some oxidization in the plates, which was evidenced by the long continued maintenance of a temperature about 5 degrees C. above the surrounding atmosphere when the liquid was first removed from the cell. Later observations, however, did indicate injury, as explained later. Further tests were made at low discharge rates, such as would be most commonly met in telephone service.

No. 20 shows a charge at 60 amperes, followed by a 5-ampere discharge. Contrary to expectation, the efficiencies thus obtained instead of being higher, appeared to be lower than at the higher ampere rate. This was later found to be due to a decrease in ampere hour capacity.

No. 21 shows a similar discharge at 10 amperes.

As No. 22 and No. 23 were incomplete and lacking in data, the curves were not plotted. The succeeding curves up to and including No. 32, all show low efficiencies, indicating that the cell actually did suffer injury from some of the abnormal conditions imposed upon it in the early part of the test, as e. g. in No. 18, when the electrolyte was removed on full charge.

No. 33 was a reverse charge, to be followed by a direct charge. This reverse charge of 470 ampere hours seemed to impart a very slight negative charge, which, however, amounted to only about one-quarter of an ampere hour.

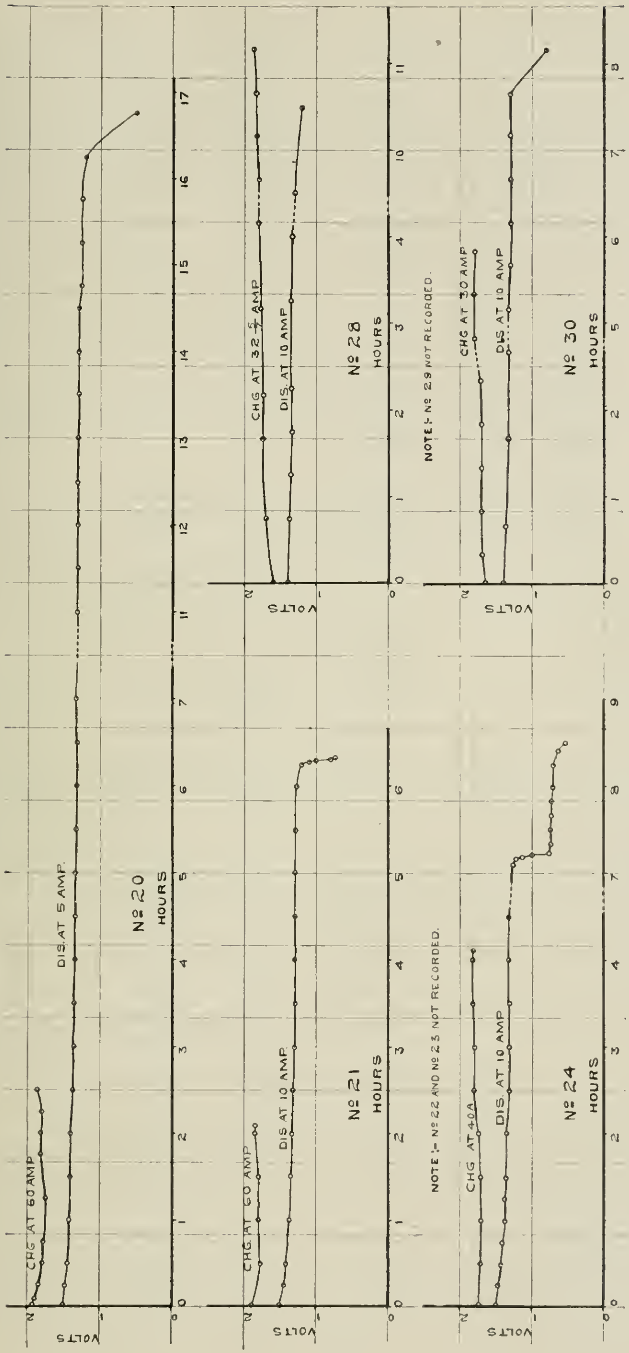

CHG AT 60 AMP
DIS. AT 5 AMP.
№ 20
HOURS
VOLTS
0
1
2
0
1
2
3
4
5
6
7
11
12
13
14
15
16
17
CHG AT 60 AMP
DIS. AT 10 AMP.
№ 21
HOURS
VOLTS
NOTE:- № 22 AND № 23 NOT RECORDED.
CHG AT 40A
DIS. AT 10 AMP.
№ 24
HOURS
VOLTS
8
9
CHG AT 32 5/7 AMP
DIS. AT 10 AMP
№ 28
HOURS
VOLTS
NOTE:- № 29 NOT RECORDED.
CHG AT 30 AMP
DIS. AT 10 AMP
№ 30
HOURS
VOLTS

Fig. 4.

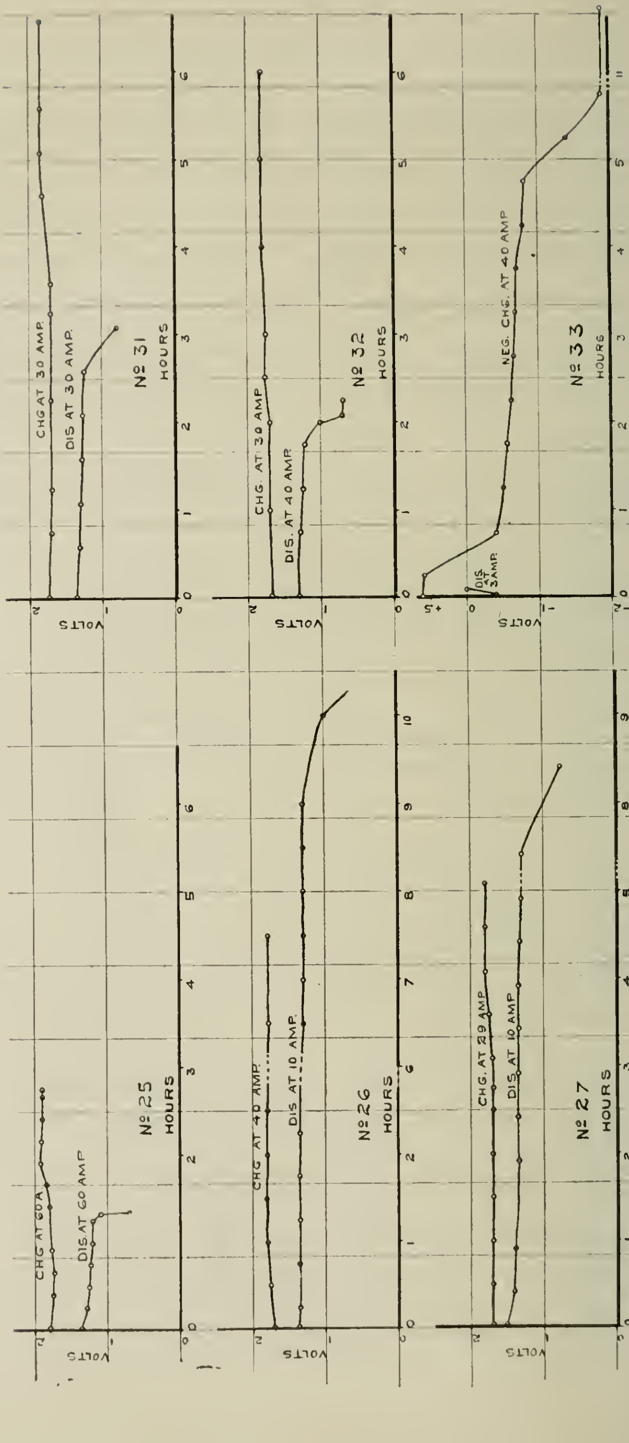

CHG AT 30 AMP.
DIS AT 30 AMP.
Nº 31
HOURS
VOLTS
CHG. AT 30 AMP
DIS. AT 40 AMP.
Nº 32
HOURS
VOLTS
NEG. CHG. AT 40 AMP
DIS. AT 3 AMP.
Nº 33
HOURS
VOLTS
CHG AT 60 A.
DIS. AT 60 AMP
Nº 25
HOURS
VOLTS
CHG AT 40 AMP.
DIS AT 10 AMP.
Nº 26
HOURS
VOLTS
CHG. AT 29 AMP
DIS AT 10 AMP
Nº 27
HOURS
VOLTS

FIG. 5.

No. 34, a much prolonged and thorough overcharge was designed to bring the cell up to its original full capacity. Its only effect was to very slightly increase the capacity.

After the 34th discharge was complete, the electrolyte was removed from the cell and placed in a bottle. The cell was then rinsed with clear water and the rinsings added to the liquid in the bottle. The amount of sediment was then determined, as explained later. After rinsing out the cell, instead of returning the alkaline solution, pure water was used, which was allowed to remain during the next charge.

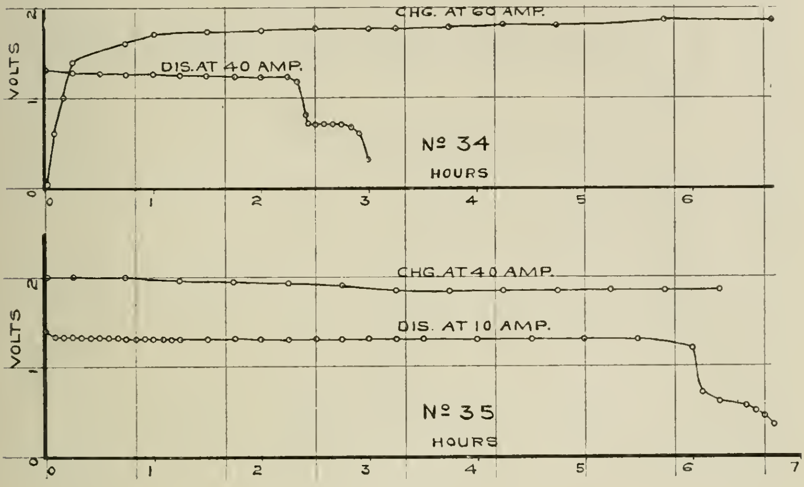


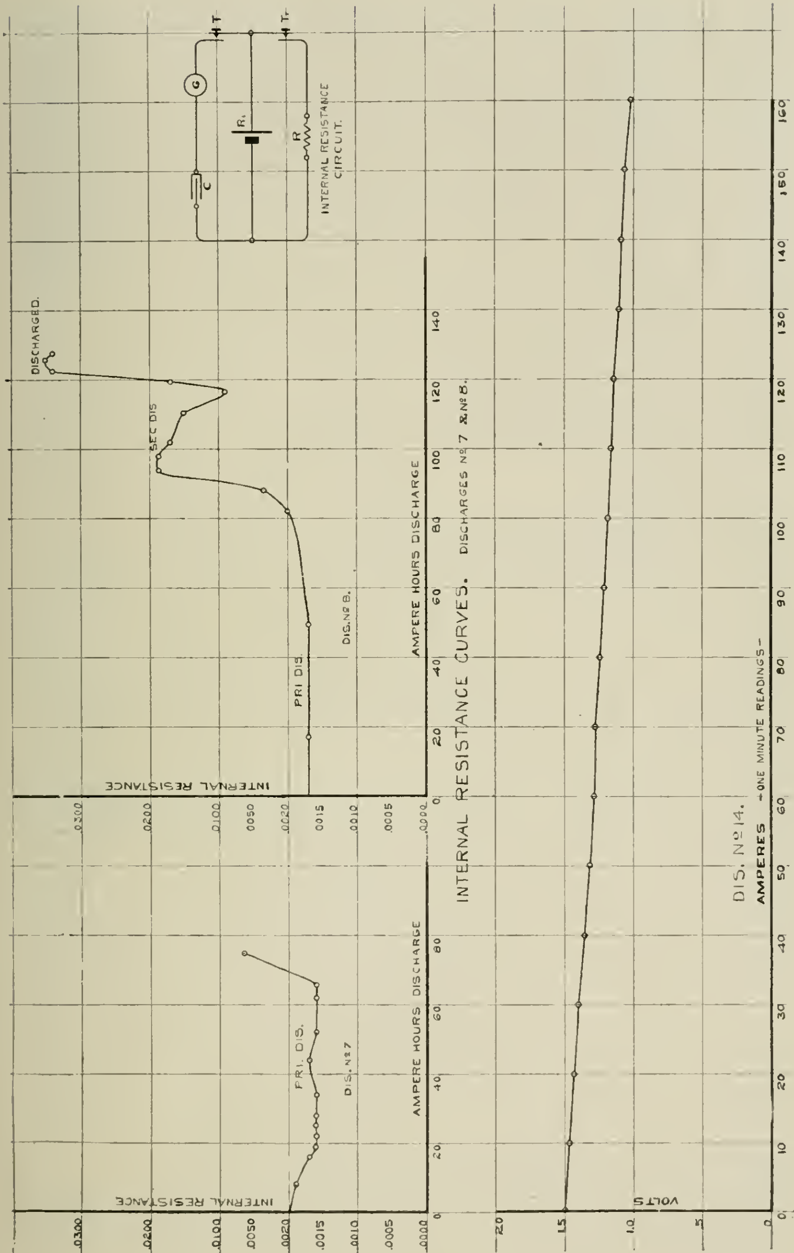
FIG. 6.

No. 35 was an experimental charge to determine whether the cell would charge with a very weak solution, and to what extent. Obviously, a small amount of the alkaline solution must have been retained in the oxide pockets, sufficient to give the new liquid a considerable current-carrying capacity. In fact, the conductivity proved to be nearly as good as with the regular solution. This fact is shown by the curves.

It has been stated by some authority that the functions of the alkali is to give conductivity to the electrolyte. From this we should expect that the strength of the solution would have no influence over the charging process so long as the given necessary current is allowed to pass. The test, however, actually showed that the ampere hour capacity was diminished about 20 per cent by this change of electrolyte from a strong to a very weak solution, although the nature and form of the charge and discharge curves for both kinds of electrolyte were practically identical.

TABLE OF EFFICIENCIES, ETC.

No. of Charge.	Ampere Rate.		Mean Voltage.		Ampere Hours.		Watt Hours.		Ampere Hours.	Watt Hyurs.	Hours.		Charge. A. H. % of Rating.	Discharge.
	Charge.	Discharge	Charge.	Discharge	Input.	Output.	Input.	Output.	% Effect.	% Effect.	Charge.	Discharge		
1......	30	30	1.71	1.26	345.0	112.5	590.	142.0	33	21	11.5	3.75	310.	Primary.
2	40	30	1.79	1.28	123.2	082.5	221.	105.6	67	48	3.08	2.75	112.	Primary.
3	40	40	1.76	1.26	123.2	106.8	217.	135	87	62	3.08	2.67	112.	Primary.
4......	60	60	1.81	.90	135.0	120.0	244.	108.0	89	44	2.25	2.00	122.	Primary and Sec.
5......	80-70	35	1.80	1.12	168.1	087.5	303.	98.0	52	32	2.33	2.50	153.	Primary and Sec.
6......	65	35	1.78	1.06	102.0	078.8	182.	83.5	77	46	1.57	2.25	093	Primary and Sec.
7......	60	50	1.77	1.21	195.0	075.0	345.	91.0	38	26	3.25	1.50	177.	75% Primary.
8	60	10-75	1.76	.70	165.0	127.5	290.	89.3	70	31	2.75	3.00	150.	Primary and Sec.
9......	60	60	1.72	1.20	060.0	037.2	103.	44.6	62	43	1.00	0.62	055.	Primary.
10......	60	60	1.75	1.18	060.0	045.0	105.	53.1	75	53	1.00	0.75	055.	Primary.
11......	60	30	1.75	1.26	060.0	045.0	105.	56.7	75	54	1.00	1.50	055.	Primary.
12......	30	30	1.68	1.25	060.0	048.0	101.	60.	80	59	2.00	1.60	055.	Primary.
13......	30	60	1.65	1.17	060.0	045.0	099.	52.6	75	53	2.00	0 75	055.	Primary.
14......	60	10.160	1.70	1.25	030.0	021 3	051.	26.6	71	52	0.50	0.25	027.	75% Primary.
15......	60	100 int.	1.83	1.00	150.0	083.0	275.	83.0	55	30	2.50	0.83	136	Total.
16......	60	5	-1.66	-0.01	510.0	000.10	847.	00.00	0	00	8.50	0.02	460	Total.
17......	60	60	1.70	1.15	405.0	100.0	688.	115.0	24.6	17	6.75	1.67	370	Primary.
18......	60	60	1.71	.93	150.	064.8	256.	60.0	43	23	2.50	1.08	136	Primary.
19	60	60	1.81	1.19	195.	105.0	353.	125.0	54	35	3.25	1.75	177	Primary.
20.....	60	5	1.81	1.33	150.	83.75	272.	111.	56	41	2.5	16.75	136	Total.
21... ..	60	10	1.82	1.32	126 5	62.50	230.	82.5	49	36	2.1	6.33	115	Primary.
22......	40	....	1.75	....	120.	....	210.	....	....	....	3.0	....	109	Total.
23......	60	20	....	....	60.	....	....	....	....	....	.5	....	59	Primary.
24......	40	10	1.77	1.20	165.	85.00	291.	102.	5	35	4.1	8.5	150	Total.
25......	60	60	1.83	1.23	165.	80.00	302.	98.4	48	33	2.75	1.33	150	Primary.
26......	40	10	1.78	1.31	300.	102.50	534.	134 3	34	25	7.5	10.25	272	Primary.
27......	29	10	1.72	1.34	147.	84.00	253.	112.6	57	44	5.1	8.50	134	Primary.
28......	32 5-7	10	1.77	1.33	365.	115.00	646.	153.	32	24	11.2	10.50	332	Primary.
29......	30	10	1.77	1.32	152.	88.00	269.	116.	....	....	....	8.80	....	Primary.
30......	30	10	1.75	1.33	175.	82.00	306.	109.	47	36	5.8	8.20	159	Primary.
31......	30	30	1.75	1.27	198.	93.00	347.	118	47	34	6.6	3.10	180	Primary.
32	30	40	1.76	1.15	210.	90.00	370.	103.5	43	28	6.0	2.25	191	Primary.
33......	40	3	-1.37	-.20	470.	00.25	644.	.05	.05	.008	11.75	0.80	437	Total.
34	60	40	1.75	1.14	405	96.80	709.	110.4	24	16	6.75	3.00	368.	Total.
35......	40	10	1.92	1.12	250	67.50	480.	75.6	27	16	6.25	6.75	227	Total.



INTERNAL RESISTANCE CURVES. DISCHARGES No 7 & No 8.

VOLT-AMP. CURVE. DIS. No 14 FIG. 7.

In Fig. 7 is shown certain results derived from discharges Nos. 7, 8 and 14. Nos. 7 and 8 represent the internal resistance variations noted on two successive discharges. No. 7 discharge extended only through the primary part, while No. 8 extended through both the primary and secondary to zero volts. From these curves it is evident that the internal resistance is practically constant at about .0017 ohms throughout the primary discharge, and that during the secondary discharge the apparent internal resistance increases about nine fold, and that when fully discharged the resistance rises still farther, to about .0350 ohms, i.e. with a constant current of about 50 amperes. Evidently, this rise in resistance on secondary and full discharge is due to polarization.

The theoretical circuit shown on this drawing was used to determine the internal resistance of the cell.

There are several methods for finding the internal resistance, but only the following was used in this test:

Referring to the circuit (Fig. 7), a convenient formula may be derived, as follows:

Let $R =$ dead resistance in one branch of the circuit;

Let $R_1 =$ internal resistance of cell:

Let $T =$ galvanometer deflection on closing T with t still open;

Let $t =$ galvanometer deflection or closing t with T already closed;

Also let $t_1 = (T\text{-}t)$ which should equal the deflection of T with t closed;

Let C represent the capacity of the condenser and let E represent the voltage of the cell;

$T{:}t = E\ C{:}\ \frac{E\quad R_1}{R+R_1}C$, since deflection is proportional to current, and the current is a direct function of voltage and capacity.

$$T{:}t = E\ C{:}\ \frac{E\ R_1\ C}{R+R_1}$$

$$\frac{T\ E\ R_1\ C}{R+R_1} = \frac{t\ E\ C}{1}$$

$$\frac{T\ R_1}{R+R_1} = t.$$

$$T\ R_1 = t\ R + t\ R_1$$

$$T\ R_1 - t\ R_1 = t\ R.$$

$$R_1\ (T - t) = t\ R.$$

$R_1 = \frac{t\ R}{T - t}$ Substitute for t its value $(T - t_1)$, and

$R_1 = \frac{R(T - t_1)}{t_1}$ which is the formula used.

Throughout the primary discharges, the values of t and t_1 checked very closely, but beyond this, in the secondary and full discharge readings, their combined values were slightly less than T. The values of t_1 were accepted as correct, because t_1 represents a value that coexists with a current load, and this is the condition for which information is desired. Were the value of t accepted as correct, the results obtained would be for no load, when, of course, the polarization would disappear and the resistance would remain at practically the normal value. It is evident that the polarization component is proportional to the current.

Discharge No. 14, as already noted, shows the effect of increasing the current by successive uniform increments from 10 to 160 amperes.

In Fig. 1 is shown in a theoretical form the circuit that was used. As it was not found practical to use the water rheostat in this particular case, it is shown in dotted lines only.

The discharge of the cell was accomplished by reversing the generator field leads extending to the auxiliary battery. The resistance of the wiring served to hold down the current within control of the generator field regulator.

After completing the 18th charge, the electrolyte was removed and filtered through a sheet of blotting paper, to show how much sediment had been taken up by the electrolyte from the plates. No measurements were made in connection with this observation, but the volume of sediment appeared to be about one-half of a cubic centimetre.

After the 34th discharge had been run, the electrolyte was again removed and filtered. Careful measurements were made and considerable pains were taken to get accurate results. The following method was adopted:

First, the electrolyte was poured into a bottle and allowed to stand a sufficient time for the sediment to settle. The cell was rinsed with pure water and the rinsings, containing some additional sediment, were added to the liquid in the bottle. Then, when the solid matter had all settled in a thin layer of slime at the bottom, the top was carefully poured off, leaving a small quantity of liquid with the sediment at the bottom. This remaining liquid was next shaken and mixed thoroughly and then poured through a filter paper placed in a suitable glass funnel. When the liquid had all run through, the deposit was washed with clear water to remove all potash solution, so that only the actual sediment from the plates should remain on the filter paper.

When the paper was thoroughly dried, it was weighed on delicate scales. The original weight of the paper was then deducted, leaving only the weight of the sediment, as follows:

Total weight of filter paper and deposit	2.890g
Original weight of filter paper alone	1.075g
Difference equals weight of deposit	1.815g

The volume of deposit in this case appeared to be about the same as was noted in connection with the observations made after the 18th charge.

The first deposit may have consisted partly of foreign matter collected on the surface of the plates and inside the can in the process of manufacture. The second deposit, however, must have escaped entirely from the plates, showing that there is at least a slight gradual loss of the active material from the oxide pockets.

Should the question be raised that the first deposit may have been made up entirely of foreign matter, and that the latter deposit may have been caused entirely by abnormal use of the cell, it can only be said that such a supposition seems very improbable.

VOLTAGE DISTRIBUTION RESPECTING CELL CASE.

Observations were made and readings taken to determine the voltage condition existing between the case and the elements during charge and discharge. Such data would be of assistance in case it were suspected that any cell was grounded on the case.

VOLTAGE DISTRIBUTION TABLE.

+ to —	+ to case.	— to case.	+ to case % of total.	Condition of cell.	Notes.
1.20	.34	.83	28 per cent	Half discharge.	Discharge at 40 A.
1.56	.62	.94	40 per cent	Full charge.	No load.
1.79	.68	1.06	38 per cent	Half charge.	Charge at 60 A.
1.24	.51	.73	41 per cent	Discharged.	60 amperes.
1.20	.44	.73	37 per cent	Discharged.	60 amperes.
1.15	.35	.78	23 per cent	Discharged.	60 amperes.
.62	—.15	.77	—24 per cent	Discharged.	60 amperes.
—.40	—.5	.10	13 per cent	Discharged.	60 amperes.
1.78	0.70	1.07	39 per cent	Charged.	70 amperes.
—1.89	—1.30	—.6	68 per cent	Neg. charge.	60 amperes.

It will be noted that part of the observations do not check up exactly, the total voltage usually appearing greater than the sum of the two others. This may be accounted for by slight errors in reading and fluctuations in current and voltage and the drop in the terminal posts when a current was flowing. From the table it is evident that, while the proportions are not nearly constant and at conditions approximating complete discharge, the variations are wide, still, throughout the greater part of normal charge and discharge and when fully charged, their ratios are fairly close e. g.; under normal working conditions the voltage from the positive terminal to the case should be between 28 per cent and 41 per cent of the total voltage.

Concerning the reverse charging, it is interesting to note that a special modified form of this treatment may be used with good effect for recuperating weak cells. It is claimed by good authority that in all ordinary cases a cell may be brought back to its original ampere hour capacity by using the steel can for the positive pole of the battery and charging through the nickel pole in the reverse direction; *i.e.*, by making the plates containing the nickel oxide negative with respect to the retaining case, and leaving the plates containing iron oxide neutral. The cell thus connected should be kept on charge for about ten hours at a high rate, e. g. 75 amperes for the E-18 size. The potash solution should then be renewed and the cell reconnected and given a prolonged direct charge under normal conditions, as for a new cell. As this method was not suggested till after the testing was discontinued, no further data was obtained concerning it.

The action of this cell is based on certain laws governing the oxidization and reduction of the oxides of nickel and iron when immersed in a suitable alkaline solution and subjected to the chemical action of an electric current.

The present investigation does not carry the experimental work beyond the observation of phenomena characteristic of the complete and assembled cell. Further data has been compiled from various sources concerning the theory of the cell and its chemical properties. A European authority states that the active iron material, consisting of iron and peroxide of iron, may be made by passing a current of hydrogen over pulverized sesquioxide of iron at a temperature of 480 degrees C. He states that a better method is not to use quite so high a temperature, and advises mixing in ammoniated copper and oxide of mercury, from which are obtained granules consisting of a particle of iron coated with a porous copper amalgam and oxide of iron in a very finely divided state.

Another authority claims that the first result of any electrical activity in the cell may be described as the transferance of oxygen from one electrode to the other through the medium of water. He has pointed out that any of the metals whose oxides are insoluble in alkalines may be used as electrodes in alkaline accumulators e.g. cadimum, iron, nickel, copper, mercury and silver.

Chemical authority tells us that there is a series of oxides and hydroxides for iron and a somewhat similar series for nickel.

The chief of these may be listed as follows:

TABLE OF IRON AND NICKEL OXIDES.

Metal.	Iron.	Nickel.
Symbol.	Fe.	Ni.
Atomic weight.	55.6	58.24
Valence,	Bivalent and Trivalent.	Bivalent, Usually.
Specific gravity,	7.8	8.8
Oxides No. 1.	$Fe_2\ O_3$	$Ni_2\ O_3$
No. 2.	$Fe_3\ O_4$	....
No. 3.	Fe O	Ni O
Hydroxides No. 1.	Fe (O H)	....
No. 2.	....	$Ni\ (O\ H)_2$
No. 3.	$Fe\ (O\ H)_3$	$Ni\ (O\ H)_2$
No. 4.	$Fe_2\ O\ (O\ H)_4$	....
No. 5.	$Fe_3\ O_4\ (O\ H)_6$	....

This list of oxygen compounds is presented merely to illustrate the nature of these two metals respecting their power to form a series of similar compounds. Only a part of these oxides are supposed to take a part in the chemistry of the active materials. Several of these compounds undoubtedly enter into the reactions which occur in operating the cell. It is believed that the actual reactions are complex, and that different combinations occur at different stages of the charge and discharge, and this accounts for the secondary or low voltage which is maintained during the latter part of a total discharge, and also the similar analogous steps shown in the curve of negative charge. Certain of the reactions that occur are supposed to be somewhat simple and others more complex. By means of calculations based on chemical theory, it may be proved that nickel oxides give the following theoretical capacities:

1st. Nickel peroxide ($Ni\,O_2$) reduced to nickelous oxide (Ni O) gives 267.85 A. H. per pound.

2d. Nickel peroxide (Ni O 2) reduced to nickel sesquioxide (Ni 2 O 3) gives 133.92 A. H. per pound.

3d. Nickel sesquioxide (Ni 2 O 3) reduced to Ni O gives 146.88 A. H. per pound.

Mr. Edison claims that the first reaction is of chief importance, but others claim that the other two are equally or more characteristic of the activities of discharge in the Edison type of cell.

It should be observed in this connection that the electrolyte should never be allowed to fall sufficiently low enough to expose the plates to the air when being charged or when standing fully charged, as the iron oxide particles in the negative plates will rapidly take up too much oxygen and become ruined or injured, and so permanently diminish the ampere hour capacity of the cell. This fact explains the low capacities noted after the 18th charge, when the cell was allowed to stand charged for nine days with the electrolyte removed. The total depreciation, so far as noted, amounted to about 30 per cent of the original or rated ampere hour capacity, and seemed to be due entirely to the removal of the electrolyte, as explained heretofore.

Although the two types of accumulator, nickel-iron and lead, have many points in common, and to about the same degree, still there are prominent characteristics peculiar to each, which determine any particular adaptability and superiority in certain given fields of service.

It is at once obvious that the lead cell must find its chief natural usefulness in connection with large power stations, where the requirements call for a large capacity and where the battery is subject to very little or no mechanical influence beyond that incident to its fundamental activities in charging and discharging. Automobile work introduces serious mechanical disturbances that a lead cell cannot endure without serious deterioration. Here the nickel oxide cell finds its field of usefulness, because of its indestructability and flexibility of operation.

Intermediate between these extremes are to be found a great variety of applications for storage batteries where local conditions and first cost may largely determine the selection of battery; as, for example, in common battery telephone service.

To facilitate comparison, a table may be compiled showing the relation between the two types of battery, as shown herewith.

Two supplementary tables are first shown, in which specific cases are investigated for the purpose of deriving a part of the data for the general table which follows thereafter.

TABLE SHOWING RATIO OF PLAN AREAS AND VOLUME FOR BATTERIES OF SIMILAR VOLTAGES (24 V.)—DATA BASED ON SPECIFIC CASES.

Descriptive.	Lead Cell.	Edison Cell.
Size Cell.	"E-7."	"E-18."
Ampere hour rating	120	110
Watt hours, per cell	240	135.3
Number of Cells	11	17
Cell length,	9⅛	2⅝
Cell width.	6¾	5⅛
Cell height	11⅜	13¼
Space between Cells	½-inch.	¼-inch
Total plan space	712 square inches.	241 square inches.
Connected for 110 A. H	653 square inches.	241 square inches.
Ratio of space (110 A. H.)	100 per cent.	37 per cent.
Ratio of volume (110 A. H.)	100 per cent.	52 per cent.

WATT HOURS PER POUND OF CELL AT NORMAL RATES.

Descriptive.	Lead Cell.	Edison Cell.
Size Cell.	"E-7."	"E-18."
Mean Discharge Volts........	2.0	1.23
Discharge Current...........	15.	30.00
Discharge Hours......	8.	3.66
Ampere Hours..............	120.	110.
Watt Hours.................	240.	135.30
Pounds, per cell.	60.25	13.00
Watt Hours, per pound......	4.00	10.41

GENERAL COMPARISON TABLE (LEAD VS. EDISON CELLS).

Descriptive.	Lead Cell.	Edison Cell.
Receptacle.	Glass or Lead.	Steel.
Plates......................	Lead.	Steel.
Positive material.	Lead oxide.	Nickel oxide.
Negative material	Lead sponge.	Iron oxide.
Material retained by..........	Adhesion.	Perforated walls.
Electrolyte	Dilute acid.	Caustic potash.
Corrosiveness................	Strong.	Weak.
Specific gravity electrolyte	1.20	1.18
Int. res. per A. H. capacity....	100 per cent.	133 per cent.
Gassing on charge............	Mild.	Violent.
Product of gassing	Explosive.	Explosive.
Product of gassing...........	Corrosive.	Harmless.
Polarization	Inappreciable.	Inappreciable.
Life approximate.............	10 years.	Assumed 20 years.
Maximum cell voltage.........	2.55	1.90
Minimum cell voltage.........	1.80	1.10
Normal charge voltage	2.4	1.75
Normal discharge voltage......	2 0	1.23
Ratio of discharge voltage.....	100 per cent.	60 per cent.
Normal time of charge........	8 hours.	3¼ hours.
Normal time of discharge.....	8 hours.	3⅔ hours.
Minimum time of charge......	3 hours.	1 hour.
Minimum time of discharge....	3 hours.	1 hour.
A. H. over charge required....	10 per cent.	10 per cent.
Ampere hour efficiency........	85 to 92 per cent.	80 per cent.
Watt hour efficiency	70 to 75 per cent.	55 per cent.
Watt hour per pound of cell...	4.00	10.41
Bulk per watt hour output	100 per cent.	48 per cent.
Battery plan space ratio.... ..	100 per cent.	37 per cent.
Initial costs..................	100 per cent.	120 per cent.
Renewal costs......	100 per cent.	40 per cent.
Attendance costs	100 per cent.	50 per cent.
Internal resistance ratio.......	100 per cent.	68 per cent.

ADAPTABILITY TO TELEPHONE USE.

There are several characteristics of the Edison cell that commend its application in telephone service. Its durability, small demands for attention and general operating flexibility are much in its favor. On the other hand its normal voltage is low and is subject to a large per cent of variation. Its first cost is high and its actual life has not yet been determined. These qualities may be listed as follows:

THE EDISON CELL AND ITS QUALIFICATIONS FOR TELEPHONE SERVICE.

Superior Qualities.	Inferior Qualities.
Construction durable.	Voltage low.
Attendance small	Voltage variation great.
Maintenance slight.	First cost high.
Internal resistance low.	Electrical efficiency low.
Corrosiveness slight.	
Volume small.	

As the lead cells and the nickel-iron, or Edison cells, constitute the only storage batteries of any considerable importance, only these two types will be compared.

Owing to the very thorough construction and special precesses involved in its manufacture, the present cost of the Edison cell is high. In fact the present prices prohibit the general adoption of this cell for the great majority of storage battery applications. It may reasonably be expected, however, that the cost of the nickel-iron type of cell will soon be reduced to figures comparing favorably with the cost of lead cells as methods of manufacture become more developed and improved.

The relative approximate costs may be compared by reference to the following table:

COMMERCIAL DATA ON LEAD VS. EDISON CELLS.

Descriptive.	Lead Cell.	Edison Cell.
Size.	“E-7,”	“E-18”
Ampere hour capacity..... .	120	110
List price per cell........ ..	$14.00	$10.00
Relative price for 110 A.H. cell	$12.83	$10.00
Watt hour capacity 110 A.H. cell	220.00	143.0
K.W. hour capacity 110 A.H. cell	.22	.143
Cost per K.W. hour capacity..	$58.32	$69.93
Ratio of costs per K.W.H. capac.	100 per cent.	120 per cent.

The Edison battery equipment, on account of its greater voltage range must include certain accessories including counter E. M. F. cells with suitable switching and wiring equipment for regulating purposes. It may be noted that the initial cost of the Edison battery equipment is about twice as great as for a similar lead battery. It does not necessarily follow from this, however, that the lead battery is any chaper for maintaining service an indefinitely long time as its maintenance expense is relatively high.

The continued maintenance of a battery for a long period of time involves two factors, personal attendance and renewal of parts. The former may be said to comprise general care and repair and would be covered by the pay-roll, while the latter relates to the renewal of worn out or defective parts such as would be covered by bills for material.

As indicated in the general comparison table of lead and alkaline cells, the lead cells must require a greater amount of attention in their normal working than the Edison cells for there are more points demanding attention. Moreover, the danger from neglect is much less for the Edison cell than the lead cell. This means less expense for attendance in favor of the Edison cell.

Storage battery practice in the past has pretty thoroughly demonstrated that the average life of an ordinary lead battery, under usual conditions, is from five to fifteen years, or say ten years. There are many obvious and well-known reasons why the life of a lead cell is thus limited; e. g., gradual loss of the active material, sulphating, etc. On the other hand, there appears to be practically no chance for deterioration in the Edison cell, so long as pure water is used to replace evaporation and gassing and so long as the electrolyte is kept well above the plates. The question of renewals, therefore, is also evidently in favor of the Edison cell.

The results of this investigation may be briefly summarized as follows: 1st. The Edison cell is entirely practical in its three chief physical aspects—mechanical, chemical and electrical.

2d. Owing to its low ampere hour and watt hour efficiencies, its power consumption is large for a given output. This considerably increases its operating expense where the power rates are high.

3d. Its present relatively high initial cost must limit its general adoption only to uses for which it is especially adapted.

4th. Its application in telephone service would appear to be advantageous in small common battery exchanges because of its small demands for attention and maintenance, doubtless more than sufficient to offset the difference in initial cost.

5th. It is especially adapted to the requirements for automobile service.

DISCUSSION.

Mr. Hale—The subject we are about to discuss—the new Edison storage battery—is an attractive one. The Edison cell has aroused much interest of late, partly due to its intrinsic merits and partly on account of the eminence of its inventor.

This battery has many good points, among which may be mentioned durability, a fairly good efficiency and the ability to withstand rough usage, while its lightness makes it valuable for automobile work. It may be described as an oxygen-lift cell, in which oxygen is electrolytically conveyed from the negative or iron plate to the positive or nickel plate during charge, the caustic electrolyte remaining unchanged. During discharge the nickel oxide of the positive element is reduced to a lower form.

Dr. Kennelly, Professor of Engineering at Harvard University, has said that the Edison cell, owing to its steel construction and corresponding mechanical strength, its great durability, and the small amount of attention necessary to keep it in good working order, could be said to compare more favorably with its competitor—the dynamo—than can any other storage battery now on the market.

Mr. H. M. Beck (Electric Storage Battery Co.)—Except for the few who have had the Edison battery in hand for experimental purposes, I think there has been very little practical experience with them. In fact, here in Chicago, I have been waiting for sometime to get a few batteries so we could tell what they would do in practical use. The use of them in the telephone service is an entirely new phase of the subject to me.

I would like to ask Mr. Davis a few questions, as I am not familiar with the subject from this standpoint, and I expect there are others here tonight who are in the same position.

I will ask first, how he determines the end of a charge; when is a cell charged, or when is the time to cut off the current? I notice in a great many of the curves he shows that he starts with a given voltage and ends with a lower voltage than that with which he started. Of course the voltage is one of our most important methods of determining the proper amount of charge in a lead battery, and this, especially in the lead type, is very important. I do not suppose it is so important in this cell, except from an efficiency standpoint, but there must be some means besides voltage for determining when the cell is full and when the current is to be cut off?

Mr. Davis—The most reliable means of determining when a cell is fully charged is by a few experiments to determine what amount of charge is sufficient to get the rated ampere hour output. There seems to be no fixed voltage to be attained on full charge. For the most part, the voltage appears to rise gradually as the charge is continued, with possibly one or two exceptions shown on the curves where it was slightly less, but as a rule it is the other way. I know of no way except experimental charges to determine when a sufficient charge has been instilled.

Mr. Beck—For instance, in telephone or automobile service you use a certain amount of the charge, it may be only a small fraction; is there no way then, of telling how much to put back when you do not know what has been taken out?

Mr. Davis—That is my understanding. When the state of charge is not known approximately, the battery should be recharged. When the voltage falls below about 1.23, the battery will run for a short time on the secondary discharge. It is better practice however, from an efficiency standpoint, not to run on this secondary part of the discharge. Better results are to be obtained by recharging as soon as the primary part of the discharge is exhausted.

Mr. Beck—Then the only safe method would be (no matter how much the discharge) to put in the complete charge in order to be sure the cell was full.

Mr. Davis—For an automobile run it would be desirable to put in a full charge to make sure that there had been instilled a sufficient charge to depend upon. Of course this question would depend somewhat upon the nature of the service.

Mr. Beck—Have any tests been made to show how the cell holds its capacity? Suppose it is charged up to its full capacity and is allowed to stand, charged, for two or three days, and is then discharged. Have you any figures on the percentage of loss?

Mr. Davis—No test was conducted for allowing the cell to stand, fully charged, except in one case when the electrolyte was removed during the time in question in order to determine if there would be any injury resulting from leaving the electrolyte out. Of course, it is well known that if an ordinary lead cell is taken apart, fully charged, and allowed to stand, it will heat and the negative plate will oxidize and be ruined. In a telephone exchange, where there is a small plant, and the attendant, possibly, may not know much about a battery, he will doubtless at some time have occasion to take out one or more plates and seeing that they get hot after standing a short time, he will wait for them to get cool, and at the end of that time the plates will be ruined. In this test it was desired to see what would be the result of such treatment of the Edison cell.

Mr. Beck—In regard to the lead plates being ruined on being allowed to dry when taken out, I might make a few remarks on that subject, because it is something I am a little more in touch with. The fact is, we do not consider it the best thing for a lead cell to permit it to dry out; but on the other hand I will say that we have more than once made use of just such treatment, and it actually greatly improves the capacity of the battery. I know of a case where the electrolyte was taken out and the cells were allowed to stand for about one-half day and allowed to heat. The electrolyte was then put back and the cells charged up, and the capacity of the battery was brought up to the full amount, or 100 per cent, although it was previously only about ⅔. This is a treatment we have used a number of times in just such a way in order to get the capacity up; so that such treatment is not always ruinous to the lead battery.

Mr. W. D. Ball—Does it make any difference whether you draw the electrolyte out when the battery is charged?

Mr. Davis—That fact is only true when the battery is charged. If you discharge the battery and remove the plates there will be no chemical action or oxidation on exposure to the air.

Mr. Scheible—I would like to ask Mr. Davis why only the upper portion of the casing is corrugated?

Mr. Davis—The idea of the corrugation is to stiffen the walls of the case, which is made of very thin steel, about $\frac{1}{32}$-inch thick. The heavy nickel plating serves to protect it from oxidation. The plates are separated from the wall by a thin sheet of hard rubber. The corrugation, moreover, gives the liquid freer access to circulate on the outside next to the walls.

Mr. Scheible—Perhaps Mr. Davis stated this in his paper, but how does this cell compare with the ordinary lead cell in weight for the same watt hour capacity?

Mr. Davis—In the Edison cell the watt hour capacity is about 11 watt hours per pound of the cell, whereas in the lead cell it is only about 4 for the complete assembled cell, including the jar and electrolyte.

Mr. Scheible—How will it compare in standing the jarring?

Mr. Davis—Of course it is well known that the lead cell will not stand jarring, as, for instance, in automobile work. That is, the washing of the liquid is sure to disintegrate and wash away the active material—especially in the pasted type—whereas in this cell, the active material being retained in small pockets in the plates cannot escape, these pockets being of thin steel with walls finely perforated.

Mr. Libby—There is one point I would like to bring out. At the time Mr. Davis started on his tests, I was curious to know, first, if some of the claims made for the cell were actually true; but while inspecting these claims, practically the main point was concerning its adaptability to telephone work.

There are one or two things in connection with the cell that would seem to indicate that it was adaptable for telephone work; one of these is the internal resistance. One requirement in telephone work is to have a battery of very low internal resistance, so as to cut down the danger of cross-talk. You will recall that in the curves shown the internal resistance starts at about .0017 ohm.

In a lead battery of the same rating, the internal resistance was found to be very nearly double the amount just mentioned. You can easily see that this is because in the Edison battery the plates are close together not more than $\frac{1}{16}$-inch space between the plates. At the end of the discharge the internal resistance is about the same as for the lead battery at the beginning of the discharge, so that this particular point seems to be in favor of the Edison cell.

On the other hand, there is a disadvantage with this cell in connection with telephone work. For example, on our system (the Kellogg Switchboard & Supply Co.) we use two sets of eleven cells of battery, giving about 22 volts. The minimum voltage would be, with the lead battery, about 20, and the highest about 27. You can see whereby the initial voltage of the Edison cell, being only 1.23 volts, it necessitates a larger number of cells. Moreover, the maximum and minimum voltages run in wider ranges than on a lead cell; consequently, in order to prevent burning out supervisory and line lamps at full charge, it would be necessary to cut in counter e. m. f. cells. Mr. Davis neglected to state how he built up counter e. m. f. cells with an ordinary nickel plate and an iron plate—two plates, fastened about $\frac{1}{16}$-inch apart, which gave a counter e. m. f. of about 2 volts. This would be very inexpensive, and probably would not cost more than $3.00 per cell, so this c. e. m. f. cell cost is not very large, and is easily gotten around.

Again, a disadvantage with the cell would be in the low ampere and watt hour capacities. The cell would be a good one to use in some towns, as Mr. Davis cited, where the attendant knew practically nothing about the storage battery. I should prefer giving an attendant in such a place a cell of this kind, because it is covered over and the chances for evaporation are not nearly so great as with the lead cell, and there would not be as much danger of ruining it.

Some of you may wonder why, in some of the tests referred to, the electrolyte was left out of the cell for nine days. The reason for that was this: I have been in a great many telephone exchanges. In some I have actually seen one or two cells standing in the corner. On asking what the cell was there for, I was told that there was something wrong with it, and the attendant, not knowing what was the matter, had taken the cell out. When he came to put it back the cell did not work satisfactorily, and to his evident surprise it did not recuperate. With this test of nine days we desired to see if it was possible, after that length of time, to put the cell back into normal condition, and as Mr. Davis has shown you by the curves, he was able to get about 50 per cent of the watt hour capacity out of the cell, even after that bad treatment.

Another good point in connection with the cell, is its fine mechanical construction. On looking at a piece of apparatus that is nicely machined and covered with high tint lacquer, etc., one will admire the apparatus and workmanship. The storage battery is something you do not usually look at very carefully. If you look at the Edison cell you cannot but say it is a piece of good workmanship, and that is probably why the initial cost of the cell is high. As an illustration of the cost, for 34 "E-18" cells of the 110 ampere hour Edison type, compared with the equivalent 22 "E-7" cells of chloride battery, there is a difference in cost of about $125. For the next, or "E-27" size, there is a difference of about $175; and for the largest, or "E-45" size, of 180 ampere hours' capacity, there is a difference of a little over $200, so the difference really means quite an item.

It seems to me, from observation and from Mr. Davis' investigation, that the cell is primarily an automobile battery, and, with all due regard to Mr. Beck and his exide battery, I should say the Edison battery could be used to advantage in a large number of towns.

In this connection, I would call your attention to the fact that if, when one is out with an automobile equipped with Edison battery, he sees by his voltmeter that the voltage is beginning to fall down, he knows there is still something left, due to the secondary discharge; but if the machine is operated by a lead battery, and the voltage begins to fall rapidly, he knows he can go but a very short distance farther.

Mr. Smoot—One of the most valuable features of the ordinary lead battery is its very low resistance on short cycles of charge and discharge. Such a feature makes a battery very valuable for regulation on fluctuating loads. It would appear from the work so far along on the Edison battery that it has not that low resistance feature.

Mr. Davis—From the tests which we made it appeared that the internal resistance of the Edison cell was very low indeed. In fact, it seemed to be about 75 per cent of the resistance of the lead cell of a similar capacity.

Mr. Smoot—The resistance of the lead cell is most any quantity you want to make it, dependent on the rates of charge and discharge.

Mr. Davis—The determinations of the internal resistance of this cell were made at the normal discharge rate of 40 amperes, and I think it would be safe to say that the relative internal resistance of a lead cell of similar capacity, and worked at its normal rate, will show, as already indicated, to be somewhat greater than for the Edison cell.

Mr. Cochrane—I would like to ask what the efficiency of the ordinary cell was—I understood the efficiency of the Edison cell was about 50 per cent.

Mr. Davis—The efficiency of the lead cell is considerably higher. The ampere hour efficiency runs up to about 90 per cent on a large installation, where it would be most efficient. The watt hour efficiency would be somewhat lower—say from 70 to 75 per cent, whereas with the Edison cell the ampere hour efficiency is about 60 per cent, and the watt hour efficiency only about 50 per cent.

Mr. Blumenthal—I would like to ask Mr. Davis if he can tell us the formula for the nickel oxide and also for the iron oxide. He spoke of the relative weights of these batteries, now perhaps he can tell us about the relative space required for the use of the Edison battery. I have an idea that a special automobile or an attachment would have to be built to accommodate the extra cells.

In regard to the weight you give for the watt hour efficiency of a lead battery, was that for automobile or stationary type?

Mr. Davis—The stationary type was considered—i. e., the type ordinarily used for power station work. An Edison battery will occupy less space than this station type, but will take more space than the special automobile type of lead battery.

A list of the oxides of iron and another list of the oxides of nickel, is in the paper presented.

Mr. Edison has advanced the chemical equation, $Ni\,O_2 + Fe = Ni\,O + Fe\,O$, as representing the chief chemical reaction associated with the discharge of the cell. . Mr. A. L. Marsh, however, who has made a considerable investigation of the electro-chemical theory of storage batteries, has maintained that the equation $Ni_2\,O_4 + Fe = Ni_2\,O_3 + Fe\,O$ most nearly represents the change that accompanies the discharge.

Mr. Scheible—Are all of those oxides used in the cell, or is there a preponderance of certain kinds?

Mr. Davis—This list of oxides is presented merely to illustrate the nature of the two metals. The actual oxides which are contained in the pockets are of a complicated nature, and they are not generally known. I was unable to get the exact formulæ for them, as they are kept secret. But there are theories which give certain formulæ which are rather complicated, and I did not attempt to remember or present them. The process of preparing them is also rather complicated.

In this case, after the tests, I noticed that there were to be seen particles of mercury, indicating that mercury entered into the construction or formation of those oxides.

Samples of oxides submitted to the speaker for examination showed the iron oxide as a fine black powder while the nickel oxide appeared to be a hard green amorphous substance of a granular or lumpy texture.

Mr. Libby—You will notice on the curve that some of the one-hour charges are at 60 or 70 amperes. These tests Mr. Davis made to check up statements made that the cell absorbed about two-thirds of its charge in one hour, and we found that to be actually so—that the cell would take in about two-thirds of its charge in the first hour. That is not true of the lead battery, by any means. For the first two or three hours of charge after the lead cell is fully discharged, it will not begin to show any rise in voltage, nor take in any considerable proportion of the charge. In justice to Mr. Beck, I would like to modify a statement I made. I said that the internal resistance of a simple Edison cell was about half that of the lead cell, which is true; but taking a set of eleven lead cells, one would have to use seventeen of the Edison cells to get the same voltage. Hence, the over-all internal resistance of the 17-cell Edison battery would be only slightly lower than the over-all internal resistance of the 11-cell lead battery.

Mr. Smoot—I would like to ask if that over-all internal resistance is the resistance which would produce the difference of potential between the discharge and subsequent charge with 1½-minute cycles at very high rates? Do you find the behavior of the Edison cell similar to that of the lead battery of the same size in this respect?

Mr. Davis—I would state, in this connection, that many of these charges were at rather high rates. The advised charging rate is 40 amperes; but there are many experimental charges at 60 amperes. The idea is, that these oxides are not good conductors of electricity. However, they are contained in pockets which are of metal and hence are in immediate contact with good conductors of electricity; therefore, the current, in passing from one plate to the other, does not all pass through the oxide particles, but a part of it will go direct through the steel plates themselves, and at the surface of the steel plates water will be broken up into oxygen and hydrogen. I ascribe the difference in voltage to be due partly to this polarization effect. A variation of current causes a corresponding small variation of voltage, the latter being due chiefly to the internal resistance.

Mr. Hale—Will Mr. Davis tell us whether he subjected the cell to any rough usage in his tests to determine its availability for automobiling? I do not mean the usage the battery would receive while exceeding the speed limit on Michigan avenue, but rather its condition after completing a tour through South Chicago, Hegewisch and Blue Island, for example?

Mr. Davis—We did not exactly play football with the cell; in fact, I cannot say that we gave it any rough mechanical usage in the tests. However, that sort of test has been given to it pretty thoroughly by others. If you will read reports of certain automobile runs, you will find that in very long runs the cell holds up with practically no depreciation. The cover is sealed to the top of the can when the plates are placed inside. In the process of charging, the water in the electrolyte is decomposed and occasions a certain amount of gassing, which escapes through a kind of screen arrangement. At the same time this screen arrangement stops the escapement of the vapor or particles of the electrolyte; otherwise, the spray would escape and cause a rapid loss of the electrolyte. To replace the boiling away of the liquid, there is a filler arrangement with a spring attachment, when it is desired to add water or electrolyte. There is an automatic visual indicator attached, by means of which you can see when there has been sufficient liquid added. The cover being sealed, there is no means of determining the amount of liquid in the cell by looking at it as in an ordinary lead cell.

Mr. A. L. Marsh—I would like to ask a question regarding the different voltages of the Edison cell. Is there a rapid fall of e. m. f. at any point, or is the drop gradual?

Mr. Davis—In charging the battery under a normal charging rate of 40 amperes, the voltage at all times comes up to about 1.75 volts, and then, on discharging, it drops away to about 1.23 volts. While there is a slight, graudual decrease, it is approximately about 1.23 throughout—that is, so long as the current remains constant.

Mr. Marsh—Does the working e. m. f. fall lower than 1.23 volts at any stage?

Mr. Davis—Yes; first we have the so-called primary discharge. Beyond this point it falls to about 0.7 or 0.8 volts and continues for a comparatively short time on what is known as the secondary discharge. This secondary discharge is evidently conducted on a different kind of oxide; that is, a lower oxide, and the chemical action is evidently somewhat different. It is not advisable to run on this secondary discharge because, after such usage, a much prolonged charging is necessary to get the cell back to its normal primary condition again. This is not generally advisable as it causes low efficiency, although it will stand charging at a very high rate and the time required will not be very great. For instance, no injury comes from charging or discharging at 100 amperes or even at a higher rate for the "E 18" cell which has a normal rating of 40 amperes.

Mr. Marsh—Then there is a marked drop in voltage between the primary and secondary discharges?

Mr. Davis—Yes; there is an abrupt fall between the primary and secondary discharges. In charging there is no distinction between the primary and secondary. When the charging is begun the voltage comes right up to very nearly the highest voltage.

Mr. Marsh—That change may be due to the iron. I have experimented with the nickel oxides in connection with other metals such as cadmium and zinc, and as a general thing the e.m.f. falls gradually; there is a gradual fall from 1.6 volts (or it may run as high as 1.8 volts on full charge) down very gradually to nothing when zinc is used as the negative. At no point was there an abrupt change.

Mr. Davis—Did you find that to hold true with the nickel and iron?

Mr. Marsh—I did not experiment with the iron negative; simply with the zinc and cadmium. Only one oxide is formed with these metals, whereas with iron there are at least two. This may account for the abrupt drop in e. m. f. noticed in the Edison cell.

Mr. Smoot—I would ask what might be expected to happen if the nickel plating should be imperfect in some portion of the plates?

Mr. Davis—The plates are of steel—I might say a mild form of steel—nickel plated. The case also is nickel plated, but there seems to be no action of the electrolyte on the iron, even unprotected. Of course, if the case and plates were not nickel plated where exposed to the atmosphere they would oxidize or rust.

Mr. Smoot—My point was more with reference to the positive plate. Should the nickel plating of that plate be imperfect, what would be expected in consequence? Would not the plate be destroyed by local action?

Mr. Davis—I think no serious injury of the plate would result. The action of the cell depends on the oxide, and so far as the plate is concerned, that is merely a support to hold the oxides.

Mr. Lunn—A comparison of cells used in automobiles might be of interest. Take a type of cell one size larger than the one we have heard described—the "E-27" Edison—and a cell of the "Exide 13 M.V." Express type, of the same ampere hour capacity —168 ampere hours. The number of cells generally used in an automobile battery ranges from 20 to 40. Take, for instance, a 40-cell battery of the "Exide" type, giving a pressure across the terminals of about 80 volts. A battery of 64 cells of the Edison type is required to give the same terminal pressure. The average voltage of an Edison cell during discharge is about 1.23; the average voltage of an "Exide" cell is about 1.98. The weight of the "Exide" battery would be 1,560 pounds; of the Edison type, 1,120 pounds, the Edison battery weighing about 32 per cent less than the "Exide." The cost of the Edison battery would be about $960.00; of the "Exide" battery, between $550.00 and $600.00, or the cost of the Edison battery is almost double that of the "Exide." The watt hours per pound of complete cell are about 11.8 for the Edison type and about 8.5 for the "Exide" cell. The watt hour efficiency is the most important point in comparison, that of the Edison cell being about 46 per cent. while the watt hour efficiency of the "Exide" cell is about 70 per cent. To be sure, these figures are derived from laboratory tests, but the same factors which would cause these figures to change in practice in one case would likewise affect the other, so we could expect the same difference in efficiencies to hold. Take, for instance, a machine like the Montgomery Ward trucks. The actual monthly cost for charging current at 10 cents k.w.h. would be in the neighborhood of $60.00. The charging current for an Edison battery of the same k.w.h. capacity would be about $90.00, a difference of $30.00. This $30.00 a month, for a year and a half (about the life of a lead battery) would more than pay for a new lead battery. So I do not see where the great saving is going to be made in using the Edison battery in place of the lead battery for automobile work, especially when one costs $960.00 and the other about half that.

Mr. Beck—There was one point brought out in regard to the action of the Edison cell which in practical work would make that efficiency still lower than Mr. Lunn has made it; that is, with the lead cell you are able to tell when the battery is charged and when it is time to discontinue the charge. With this Edison cell you have no means of telling just how much e. m. f. you have taken out of the battery, but you want to know before starting out the next time that you have a full charge. Under these conditions the only way I see that you can do, is to give it a full charge each time, and in this way the actual efficiency would in practice be very much lower than the relative efficiency of the two types of cells under laboratory conditions.

Mr. Lunn—In that connection I might say that it is usually the practice to figure on how far you want to go before charging the battery, and charge accordingly. In some cases a practice is made of giving the battery a full charge after every partial or full discharge. This, of course, might bring down the efficiency of the battery very considerably.

Another point in connection with the Edison cell is its mechanical strength. The sealing on of the cover, however, has given the Edison people a great deal of trouble. They now make a practice of fusing instead of soldering the cover on to the cell proper, so as to keep the solution from eating its way out. Some of the earlier batteries gave considerable trouble on account of leakage of the electrolyte around the cover, due to imperfect soldering.

I think there is fear among the automobile men that there will yet be some development in the Edison battery which will make it impractical for general use in automobiles. The fact that the capacity is considerably decreased when the electrolyte is allowed to fall below the top of the plates is something which is likely to frighten them. I do not think there are many automobile people operating electric rigs who have not at some time suffered from that very thing, and it does not look as though the Edison battery can cure this foolish and expensive carelessness. Automobile people must learn to not let the electrolyte get below the top of the plates if they are to get good results out of any battery.

Referring to the mechanical strength of the Edison cell, I saw a cell which had been thrown out of a third story window onto the pavement. It was not broken or short-circuited, and continued to work all right.

Mr. Hale—What do you consider the practical value to the automobilist of that secondary discharge in enabling him to get home?

Mr Lunn—He can creep home on the secondary discharge if he profits by the warning that his battery is nearly discharged. A person who has operated a lead battery in an automobile for any length of time knows, however, how many miles he can run after his battery shows signs of distress, and unless he is too far away, he can get home without difficulty.

Mr. Marsh—I have tested a number of lead batteries and find that at normal discharge rates the voltage will fall to certain points and remain there for quite a length of the discharge. For instance, in one case, the voltage went gradually to about 1.9 and held that to nearly the end. Therefore the best way to determine the state of charge of the lead cell is probably by the density of the acid, not by the voltages given. In the Edison battery I have understood that the voltage falls gradually during the whole discharge, and I would like to ask whether the amount of that fall would not in some measure indicate the state of charge of the battery.

Mr. Davis—So far as was noted in the tests we conducted the fall was not gradual to a sufficient extent to give an indication. That is to say, on the primary part of the discharge, so long as the current was maintained, the voltage held up very nearly constant, until the primary was exhausted, when it abruptly fell away to the secondary part of the discharge, leaving no voltage indication on the primary which would be reliable or practical to depend upon.

Mr. Smoot—In regard to the lead battery for automobile work, the difficulty has not been to make a good lead battery, but to teach the drivers how to handle their battery. For instance, batteries in the hands of the skilled operators will give marvelous results as compared with the operation of batteries in general use,

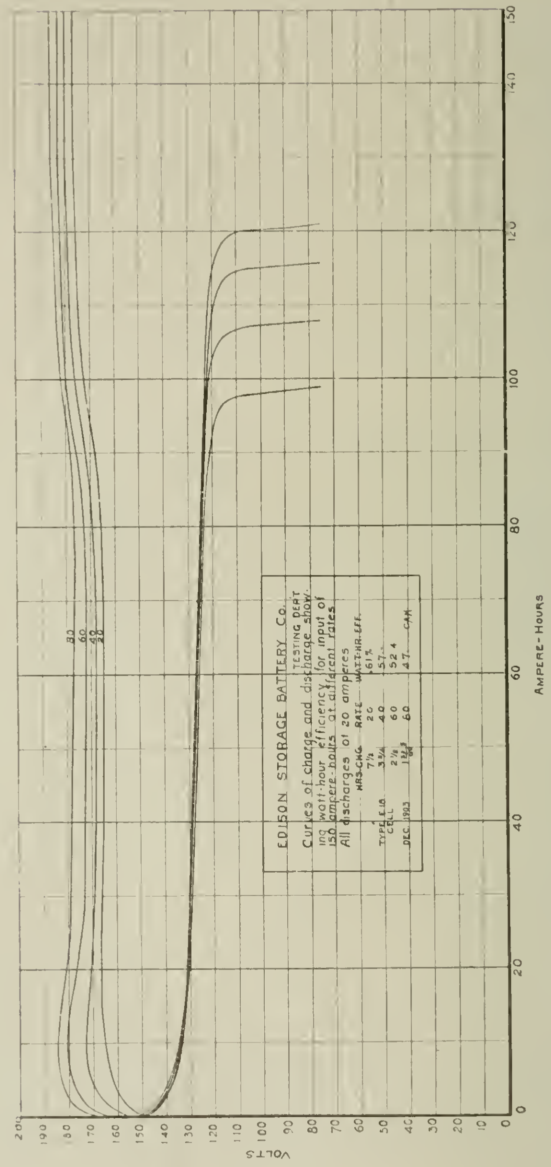

EDISON STORAGE BATTERY Co.
TESTING DEPT
Curves of charge and discharge showing watt-hour efficiency for input of 150 ampere-hours at different rates
All discharges of 20 amperes
TYPE E 18 CELL
DEC. 1903
HRS.-CHG.
7½
3¾
2½
1 23/64
RATE
20
40
60
80
WATT-HR.-EFF.
61%
57.
52.4
47.
CAH
80
60
40
20
VOLTS
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
AMPERE-HOURS
0
20
40
60
80
100
120
140
150

FIG. 8

while the battery in the hands of those unfamiliar with it will give entirely different results. It appears that the Edison battery has not had this inexperienced treatment as yet, and it seems to me a little unfair to compare it with practical tests on the lead battery.

Mr. Davis—I have read of two or three automobile tests where the Edison cell has been used in automobile work sufficient to demonstrate quite thoroughly that it will stand up in actual tests. Not that I have made that sort of test myself, but I feel well satisfied that such test has been properly made. I wish to acknowledge Mr. Libby's valued assistance in connection with the tests just conducted.

Mr. Libby—The tests made by Mr. Davis were not made for the purpose of finding out whether this was a good automobile battery, but the primary object was to find out whether the battery was a good one for telephone work. It has been previously mentioned by me that in certain cases it might be advisable to use the Edison battery for telephone work, but the tests as a whole, indicate that practically the only field for this cell, as now built, is in automobile work.

ADDENDA.

Fig. 8 represents results of certain tests made by the Edison Storage Battery Company at their own laboratory.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—September 7, 1904.

A regular meeting of the Society (No. 526) was held in the Society Rooms, Monadnock Block, September 7th.

The meeting was called to order at about 8:30 p. m. with Mr. W. L. Abbott, 2d Vice-President, in the Chair and about 54 members and guests present.

As the Minutes of the meetings held in June had been printed in the August JOURNAL, the reading of these was dispensed with.

The Secretary announced that the Board of Direction, at their meetings of July 5th and August 2d had elected the following persons into membership in the Society:

George W. Brady, Chicago, Junior.
F. A. Watkins, Chicago, Associate.
Kempster B. Miller, Chicago, Active.
Chason W. Brooks, Chicago, Junior.
Lewis M. Martin, Anita, Iowa, Junior.
C. M. Ward, Chicago, Active.
Leo C. O'Bryne, Chicago, Junior.
Fred. Norlin, Chicago, Active.

The Secretary announced the loss to the Society of three Active members, as follows:

June 11th, 1904, Mr. Guy Miltimore, of Chicago.
July 21st, 1904, Mr. A. J. Tullock, of Leavenworth, Kan.
August 20th, 1904, Gen. Charles Fitz Simons, of Chicago.

Following this announcement Mr. Layfield offered a resolution that the President of the Society appoint such committees as may be necessary for the preparation of suitable memorials of these members. The resolution was adopted.

Mr. Liljencrantz offered resolutions on behalf of the Entertainment Committee, that a vote of thanks be extended to the Illinois Central Railroad Co. and to the city authorities of Kankakee for courtesies extended to the Western Society of Engineers, on the occasion of their excursion to Kankakee, Ill., August 12th, 1904; also that a vote of thanks be tendered to the Chicago & North-Western Ry. Co. for courtesies extended to the Western Society of Engineers on the occasion of their excursion to Milwaukee August 26th, 1904. These resolutions were adopted.

There being no further business to bring before the Society the Chairman announced the subject under discussion, "Fireproof Construction," particularly of floors.

Mr. J. T. Montgomery, of the Society, presented his paper on the use of Cinder Concrete for such purposes, which was illustrated by lantern slides after the reading of the paper.

Mr. E. V. Johnson, of Chicago, was then introduced, who presented his paper on "Hollow-Tile Floor-Construction."

A general discussion followed from Herr Hagn, of Germany, and Messrs. Layfield, Mensch, Blumenthal, Condron, Ashley, Geo I. S Collins, E. V. Johnson and J. T. Montgomery.

The meeting adjourned about 10:45 p m.

EXTRA MEETING—Sept. 21, 1904.

An extra meeting of the Society (No. 527) was held Wednesday evening, September 21, in the Society Rooms. The meeting was called to order at 8:20 by Mr. J. W. Alvord, Trustee, with about 70 members and guests present.

The Secretary presented an invitation which had been sent to the Western Society of Engineers by the Chicago members of the Society of Chemical Industry, to attend a reception tendered to the visiting members of that Society of England, at the Auditorium Hotel, Friday evening, September 23.

There being no further business to come before the Society, Mr Leonce Battu was introduced, who presented his paper on "The Utilization of Exhaust Steam," the paper being illustrated by lantern slide views. At the conclusion of the reading of the paper quite a lengthy discussion followed from Messrs. Warder, Howlett, Smoot, Alvord, Junkersfeld, Blumenthal, Wellmann, Cochrane, Hine, Thurtell, Watkins, Tucker and Battu.

On motion of Mr. Tratman, a vote of thanks was tendered to Mr. Battu for his interesting paper.

The meeting adjourned about 10 p m.

REGULAR MEETING—October 5, 1904.

A regular meeting (No. 528) was held in the rooms of the Society, October 5, 1904.

The meeting was called to order at 8:15 p.m., with Past President Finley in the chair, and about 45 members and guests present.

The minutes of the meetings held September 7 and September 21 were read and accepted.

The Secretary reported, on behalf of the Board of Direction, that the following persons had been elected into membership of the Society since the last regular meeting of the Society:

Jacob G. Young, Morgan Park, Ill., Active.
James B. Marsh, Des Moines, Iowa, Active.
Oliver A. Hall, Chicago, Junior.
F. R. Ahbe, Sunrise, Wyoming, Active.
E. S. Nethercut, Chicago, Active.
Norman D. Fraser, Chicago, Associate.
E. R. Skinner, Chicago, Junior.
Emil Kurtz, Milwaukee, Wis., Associate.
H. C. Fuldner, Milwaukee, Wis., Active.
James T. Walsh, Chicago, Active.
A. M. Blumenthal, Chicago, Junior.
John Harper, Chicago, Active.
Gordon C. Abbott, Chicago, Junior.

Also, that the following new applications had been received:

Frederic W. Lucke, Chicago.
Charles A. S. Howlett, Chicago.
Augustus J. Reef, Carterville, Ill.
Chas. M. Wilkes. Chicago.
Frederic H. P. Howard, Beloit, Wis.
Charles T. Anderson, Chicago
Carl W. Birch-Nord, Chicago.

These have been referred to the Membership Committee for consideration, in the usual order.

The Secretary presented the following resolution, submitted by Mr. C. L. Strobel, Chairman of Committee on Courtesies to Foreign Engineers:

Resolved. That a vote of thanks be tendered the Illinois Central Railroad Company and the Atchison, Topeka & Santa Fe Railway Co, for courtesies extended to the guests of the Western Society of Engineers, the members of the Institution of Civil Engineers visiting in Chicago, in an excursion to South Chicago and the Drainage Canal September 29, 1904.

On motion, duly seconded, the resolution was adopted.

Prof. Severance Burrage, of Purdue University, was then introduced who presented his paper on "Sanitary Betterments of Large Industrial Establishments." The paper was illustrated by many lantern slides. and discussion followed from Messrs. Finley, McMeen, Hedrick, Dimick and Burrage.

At the conclusion of the discussion Mr. McMeen offered a vote of thanks to Prof. Burrage, on behalf of the Society, for his interesting and instructive paper, which was duly carried.

The meeting adjourned at about 10:00 p. m.

EXTRA MEETING—October 14, 1904.

An extra meeting of the Society (No. 529) was held Friday evening, October 14th, this being the first meeting of the Electrical Section for the Fall session. The meeting was called to order at 8 20 p. m. with Mr. Hale, Chairman of the Section, in the Chair, and about 60 members and guests present.

A set of rules for the government of the Electrical Section, which had been prepared by the Executive Committee of the Electrical Section last Spring, and since then revised, were read by the Secretary, and after some discussion of the matter, on motion of Mr. Eastman, duly seconded and carried, the rules were accepted.

Mr. F. M. Davis, M. W. S. E., then presented his paper—"Some Notes on the Edison Nickel-Iron Storage Battery," which was illustrated by lantern slides.

Discussion followed from Messrs. Hale, Beck, Ball, Scheible, Libby, Smoot, Cochrane, Blumenthal, Marsh, Lunn and Davis.

The meeting adjourned at 10:30 p. m.

"SMOKER"—October 19, 1904.

The Entertainment Committee invited the Society to a "Smoker," which was held in the Society's Rooms Wednesday evening, October 11, 1904. Owing to a convention in Chicago of the Association of Railway Superintendents of Bridges and Buildings many members of the Society did not attend the Smoker, but nearly 60 were present, who seemed to enjoy the provisions of the Entertainment Committee.

The Secretary, in a few words of explanation, offered for the consideration of the Society the question of an excursion this Fall, and whether to St. Louis and Thebes bridge, or to Pittsburg. This was done as a guide to the Entertainment Committee, that they might know something of the wishes of the members. Some discussion followed, but the matter was left with the Committee.

Lunch was provided, and the "Smoker" adjourned about 10:00 p. m.

J. H. Warder, *Secretary.*

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library.

Since the issue of the Journal for August, 1904, we have the pleasure to report the following additions to the library and gifts from donors named:

PUBLICATIONS FROM EDUCATIONAL INSTITUTIONS.

Armour Institute of Technology, Chicago. Year Book 1904-1905.
Bulletin, American School of Correspondence, March, 1904.
Art Institute Chicago, Annual Report 1902-1903
Bradley Polytechnic Institute, Peoria, Ill. Register 1903-1904
Brooklyn Polytechnic Institute, Brooklyn. N. Y. Register 1904-1905.
California, University of, Berkely, Cal. Register 1903-4.
Case School of Applied Science, Cleveland, Ohio. Catalogue 1903-4.
Clark University, Worcester, Mass. Collegiate Dept. Catalogue 1904.
Clarkson (Thomas S.) Memorial School of Technology, Pottsdam, N. Y. Catalogue 1904.
Cornell University, Ithaca, N. Y. Register 1902-1903.
Drexel Institute of Art, Science and Industry, Philadelphia, Pa. Year Book 1902-3.
Georgia, University of, Athens, Ga. Register 1903-1904.
Girard College, Philadelphia, Pa. Annual Reports and Catalogue 1903.
Hamilton College, Kirkland, N. Y. Annual Register 1903-1904.
Harvard University, Lawrence Scientific School, Cambridge, Mass. Catalogue 1903.
Haverford College, Haverford, Pa. Catalogue 1903-1904.
Idaho, University of, Moscow, Idaho. Catalogue 1903-1904.
Illinois, University of, Urbana, Ill. Register 1903-1904.
Iowa, State University of, Iowa City, Iowa. Bulletins No, 77, 78, 79, 1904-1905.
Kansas, University of, Lawrence, Kan. Catalogue 1903-4.
Kenyon College, Gambier, Ohio. Catalogue 1903-4.

Lehigh University, South Bethlehem, Pa. Register 1903-4.
Lewis Institute, Chicago. Annual Register 1904.
Maine, University of, Orono, Maine. Catalogue 1903-4.
Massachusetts Institute of Technology, Boston Mass. Catalogue 1903-4. Account of Foundation, Character and Equipment, 1904.
McGill College and University, Montreal. Calendar 1901-2.
Michigan State Agricultural College—Agricultural College (Mich.)Catalogue 1902-3.
Michigan, University of, Ann Arbor, Mich. Calendar 1903-4.
Minnesota, University of, Minneapolis, Minn. Year Book Engineers' Society, 1904.
Missouri, University of, Columbia. Catalogue 1903-4.
Montana, University of, Missoula, Mont. Register 1903-4.
Nebraska, University of, Lincoln. Journal of Engineering Society, 1904; Calendar 1903-4.
Nevada State University, Reno. Register 1903.
New Hampshire College of Agriculture and the Mechanic Arts, Durham. Catalogue 1903-4.
New York University, School of Applied Science. Calendar 1904-5.
Notre Dame, University of, Notre Dame, Ind. Catalogue 1902-3; and Prospectus St. Edwards Hall, 1902-3.
Pennsylvania, University of, Philadelphia. Catalogue 1903-4.
Pennsylvania, Western University of, Pittsburg. Catalogue 1903.
Pennsylvania Military College, Chester, Pa. Year Book 1903.
Pennsylvania State College, State College, Pa. Catalogue 1903-4.
Rensselaer Polytechnic Institute, Troy, N. Y. Catalogue 1904.
Rose Polytechnic Institute, Terre Haute, Ind. Catalogue 1904.
Stevens Institute of Technology, Hoboken, N. J. Catalogue 1903-4.
Swarthmore College, Swarthmore, Pa. Calendar 1903-4.
Syracuse University, Syracuse, N. Y. Catalogue 1904.
Tennessee, University of, Knoxville, Tenn. Calendar 1904-5.
Texas, University of, Austin, Texas. Catalogue 1903-4.
Tuft's College, Mass. Catalogue 1903-4.
Tuskegee Normal and Industrial Institute, Tuskegee, Ala. Catalogue 1903-4.
Vanderbilt University, Nashville, Tenn. Register 1903-4.
Washington University, St. Louis, Mo. Catalogue 1903-4
Williams College, Williamstown, Mass. Catalogue 1903-4.
Wisconsin, University of, Madison, Wis. Catalogue.
Wooster, University of, Wooster, Ohio. Catalogue 1903-4.
Worcester Polytechnic Institute, Worcester, Mass. Catalogue 1903-4.
Yale University, New Haven, Mass. Catalogue 1903-4.

BOOKS PURCHASED.

Handbook of Practical Gas Fitting, by Walter Grafton.
Timber, by Paul Charpentier.
Coal Statistics for 1904, by Alder & Ruley, Philadelphia.

MISCELLANEOUS GIFTS.

University of Illinois, Pam. Bulletin, Vol. I, No. 20, "The Coals of Illinois, their composition and analysis," by S. W. Parr.
University of Illinois, "Chemical Survey of the Waters of Illinois, reports for the years 1897-1902." By Palmer.
Ripley, Jos., M. W. S. E., Sault Ste. Marie, Mich. "Statistical report of lake commerce passing through canals at Sault Ste. Marie (Michigan and Ontario), 1903. Pam.
Michigan Horticultural Society, "32d annual report of Michigan, 1902." Cloth.
Michigan, City of Petoskey, Board of Public Works (Fred. T. Williams, City Engineer), two pamphlets, 1st and 2d annual reports, 1903-4.
Maignen, P. J. A., Philadelphia. "The Lower Roxborough Preliminary Filters, 1904." Pam.
City Club of Chicago, "Report on Police Discipline and Administration," by Piper. Pam.
Wright & Co. (Alexander) London, "Description of Simmance-Abady Photometer." Pam.

University of Montana, Missoula, Mont. "Announcement of Inter-Scholastic Meet, 1904. Bulletin No. 21. "Lichens and Mosses of Montana, Bulletin No. 19" Two pam.

Walmsley, R. Mullineaux, London, (Principal, Northampton Institute) "Transatlantic Engineering Schools and Engineering, 1904." Pam.

Strobel, C. L., M. W. S. E., Chicago:
"Water Supply and Irrigation Papers, Nos. 81, 90, 91." Pam.
U. S. Geol. Survey Bulletins Nos. 214-216." Pam.
Technisches Auskunftsbuch für das Jahr 1904, by Joly. Cloth.

Tratman, E. E. R., M. W. S. E., Chicago:
"Report R. R. & W. Com. of Ills., 1903." Flexible leather.
"Decisions and Opinions 1889-1903." Flexible leather.
"Traité Theorique et Pratique de Metallurgie Generale," by L. Babu. Cloth.
"9th, 10th, 13th and 19th annual reports Illinois Society of Engineers and Surveyors."
"Administration Report on the Railways in India for calendar year 1902." Bds. By A. Brereton.
"Administration Report of the Railways in India for calendar year 1903." By Hodson. Bds.
"A Clean Chimney—the Economical Burning of Coal without Smoke," by A. Bement. Cloth.
"Proceedings of the 30th annual convention of the Association of Ry. Sups. of Bridges and Buildings, Oct. 1903." Pam.
"Coal is King," by Huyette, M. C. Cloth.
"Controle des Installations Electriques," by Monmerque. Cloth.
"Annual Report of the Dept. of Railways and Canals, Dominion of Canada, 1901-2." Pam.
"Report of Commission of Irrigation and Water Rights, Territory of Mexico, Dec. 15, 1898." Pam.
"Final Report of Committee on Standard Specifications for Cast-iron Pipe." Pam.
"Journal of the New England Water Works Association, June, 1902." Pam.
Sundry Journals W. S. E. Pams.
"Letter from the Secretary of War, House of Representatives." Pam.
University of Illinois, Bulletin, Vol. I, No. 20, "The Coals of Illinois," by S. W. Parr.
"Notice sur le Port de Ponta-Delgada, Exposition Universelle De, 1900." Pam.
"New South Wales Government Railways and Tramways, Report of the Railway Commissioners for the year 1902-3." Pam.
"The Fish Propeller," Limbeck. 1904. Pam.
"Belleville Generators," (in French and English). Pam.
"International Assoc'n St. Ry. and Light Rys." (German). Pam.

McGraw Publishing Co., New York, two cloth bound books, "Types and Details of Bridge Construction," by Frank Skinner. "Maxwell's Theory and Wireless Telegraphy," by Poincare and Vreeland.

Michigan Military Academy, Orchard Lake, "Views of the Academy and its Surroundings." Pam.

Michigan College of Mines, Year Book of the Michigan College of Mines, Houghton, Mich., 1903-4. Pam.
Graduates of the M. C. of C., June, 1904. Pam.

Richardson Clifford, "The Constitution of Portland Cement from a Physico-Chemical Standpoint." Pam.

Lawrence, Mass., Water Board, "Annual report of the Water Board to the City Council of Lawrence, for the year 1903." Pam

Newport, Kentucky, Water Works, W. L. Glazier, Supt., five pamphlets, "Annual reports 1898, 1899, 1900, 1902."

Illinois Manual Training School Farm, Glenwood, Ill., "16th annual report, 1902-3."

Danville, Va., Water, Gas, and Electric Light Departments, "Annual reports dated May 10, 1904, for 1903." Pams.

Philadelphia Bureau of Surveys, Geo. S. Webster, Chief Engr., "First annual message of Mayor Weaver and annnal reports Dept. Public Works, etc., Bureau of Surveys." Cloth.

Rafter, G. W. Rochester, N. Y.:

"Treatment of Septic Sewage," by Rafter. Bds.

"Report of the State Water Storage Commission, with list of plates illustrating the text of this report, 1903." Pams.

Also "Report of the State Water Storage Commission, 1903." Cloth.

"American Society of Civil Engineers, 'The Flow of Water over Dams.'" Pam.

"Water Supply Paper, U. S. Geol. Survey, No. 80, 'Relation of Rainfall to Run-off.'" Pam.

"Natural and Artificial Forest Reservoirs of the State of New York." Pam.

"Future Water Supply of the Adirondack Mountain Region, and its relation to enlarged canals in the State of New York." Pam.

"System of Domestic Water Supply in the vicinity of the City of Lockport, N. Y., 1903." Pam.

"Present and proposed Waterways in the State of New York, 1903." Pam.

"Summation of the Barge Canal Question." Pam.

"Deep Waterways rather than Barge Canal." Pam.

U. S. Navy Dept., Bureau of Steam Engineering, "Report of U. S. Naval 'Liquid Fuel' Board of Tests on Hohenstein Water Tube Boiler, 1904." Pam.

Audel & Co. (Theo.) New York, "Self-propelled Vehicles," revised edition, by Homans. Cloth.

Oakley, Jno. T., Commissioner of Water Supply, Gas and Electricity, New York, "Report on Additional Water Supply for New York, 1904." Cloth.

Talbot, Prof. A. N., M. W. S. E., University of Illinois, "Bulletin No. 1 of U. of I. Engineering Experiment Station, Tests of Reinforced Concrete Beams." Pam.

Battu, Leonce, Chicago, two pam., "Reports on Steam Turbines," by Rateau. 1903.

Clark, M. C., New York, two cloth bound volumes, "Cement, Mortar and Concrete," by M. S. Falk. "Rock Excavation—methods and cost." Gillette.

Poetsch, C. J., M. W. S, E., City Engineer, Milwaukee, "Annual report, Board of Public Works, Milwaukee, 1903." Pam.

General Electric Co., Chicago, "Chicago Electrical Handbook." Cloth.

GOVERNMENT PUBLICATIONS.

U. S. Geol. Survey, Dept. of Interior. (Pamphlets.)

Production of Asphaltum and Bituminous Rock. Hovey. 1903.
Production of Monazite and Zircon. Pratt. 1903
Production of Salt in 1903. Hovey.
Production of Asbestos in 1903 Pratt.
Production of Talc and Soapstone in 1903. Pratt.
Production of Phosphate Rock in 1903. Hovey.
Production of Fluorspur and Cryolite in 1903. Pratt.
Production of Lithium in 1903. Pratt.
Production of Manganese Ores in 1903 Pratt.
Production of Barytes in 1903. Pratt.
Production of Flint and Feldspar in 1903. Ries
Production of Gypsum in 1903.
Production of Arsenic in 1903. Struthers.

U. S. Geol. Survey, Dept. of Interior.
- Production of Antimony in 1903. Struthers.
- Producıion os Glass Sand in 1903. Coons.
- Production of Borax in 1903. Yale.
- Production of Graphite in 1903. Pratt
- Production of Lead in 1903. Kirchhoff.
- Production of Zinc in 1903. Kirchhoff.
- Production of Copper in 1903. Kirchhoff.
- Production of Magnesite in 1903. Yale.
- Production of Aluminum and Bauxite in 1903. Struthers

Professional Papers, Nos. 24, 25, 26, 27.
Bulletins Nos. 232, 233 and 241.
Water Supply and Irrigation Papers, Nos. 95, 96, 101, 102, 104.
Manufacture of Coke in 1903.
Occurrence of Sulphur and Pyrite and production in 1903.
The Stone Industry in 1903.
Statistics of the Clay-working Industries in U. S. 1903.
U. S. Dept. Agriculture, Bureau of Forestry (Pamphlets):
- Suggestions to Prospective Forest Students.
- Practical Assistance to Tree Planters.
- Practical Assistance to Farmers, Lumbermen and others in handling Forest Lands,
- Exhibit of Tree Planting on a Model Prairie Farm at the Louisiana Purchase Exposition.
- The Timber of the Edwards Plateau of Texas. Bray.
- Forest Resources of Texas. Bray.
- The Forests of the Hawaiian Islands. Hall.
- Cross-tie Forms and Rail Fastenings, with special reference to treated timbers. von Schrenk. 1904.

U. S. Dept. of Agriculture, Office of Experiment Station:
- Current Wheels, their Use in Lifting Water for Irrigation. Bulletin No. 146.
- Preparing Land for Irrigation and Methods of Applying Water. Bulletin No. 145.
- Irrigation in Northern Italy. Mead. 1904.
- Irrigation and Drainage Investigations. Teale. 1904.

EXCHANGES.

American Society of Civil Engineers, "Transactions, Vol. LII, June, 1904." Pamphlet.

Boston Society of Civil Engineers, "Constitution and By-Laws and List of Members, 1904." Pamphlet.

Canadian Society of Civil Engineers, 2 pamphlets, "Vol. XIII, Part II, Transactions Oct.-Dec., 1899;" "Vol. XVII, Part I, Transactions Jan.-June, 1903."

Engineers' Club of Philadelphia, "Directory of Club, Charter and By-laws, 1904." Half leather.

Indiana Engineering Society, "Proceedings of the 24th Annual Meeting, January, 1904." Pamphlet.

Indiana State Geologist, W. S. Blatchley, "28th Annual Report, Dept. of Geology and Natural Resources, 1903." Cloth.

Iowa State Board of Railroad Commissioners, "26th Annual Report for 1903." Cloth.

Metropolitan Water and Sewerage Board, Boston, 2 vols., cloth: First and Second Annual Reports—1902 and 1903.

League of American Municipalities, Des Moines, Iowa, "Bulletin No. 1, Vol. 2, September, 1904."

Michigan State Board of Health, 13th Annual Report, 1902. Cloth.

New Jersey State Board of Health, 27th Annual Report of the Bureau of Vital Statistics for 1903. Cloth.

New England Cotton Manufacturers' Association, Boston, "Transactions, annual meeting, April, 1904." Bds.

Northeast Coast Institute of Engineers and Shipbuilders, "Transactions 20th Session, 1903-4." Half leather.

Scranton Engineers' Club, Scranton, Pa., "Directory of Scranton Engineers' Club for 1904." Pamphlet.

Stevens Institute of Technology, Year Book, 1904-5. Pamphlet.

University of Wisconsin, Madison, Wis., "Bulletin No. 79, Engineering Series. Vol. 2, No. 10." Index to Vol. 2 (1897-1903). Pamphlet.

Wisconsin Geological and Natural History Survey, E. A. Birge, Director, "The Baraboo Iron-bearing District of Wisconsin." Pamphlet.

TRADE CATALOGUES.

Abendroth & Root Mfg. Co.:
"Root Spiral Riveted Pipe." Pam.
"Root Sectional Water Tube Boilers and Exhaust Heads, etc." Pam.

Abner Doble Company, San Francisco, Cal. "An Investigation of the Doble Needle Regulating Nozzle." Pam.

Bullock Electric Mfg. Co., Sundry Bulletins, 1904. Pam.

Crosby Steam Gage & Valve Co., Chicago. Cloth Bound Catalogue, 1904.

Dodge Manufacturing Co. "Condensed Price List of Power and Transmission Goods," 1904.

General Construction Co., Seattle, Wash. Catalogue, 1904.

Harrison Safety Boiler Works, Philadelphia "Cochrane Separators."

Jeffrey Mfg. Co., Columbus, Ohio "Jeffrey Water Elevators."
"Century Rubber Belt Conveyors." Pam.

Martin Grate Co. "Martin Anti-friction Rocking Grate for Steam Boilers."

Pollock Company, the Wm. B., Youngstown, Ohio "Blast Furnace Plants, etc." 1904. Pam.

St. Joseph Boat Mfg. Co., St. Joseph, Mich. (Ernest F. Smith, M. W. S. E). Catalogue, 1904. Pam.

Wellman-Seaver-Morgan Co., Cleveland, Ohio. "The Sargent Complete Expansion Gas Engine." Pam.

BOOK NOTES.

The Constitution of Portland Cement, from a physico-chemical standpoint. Clifford Richardson. An address before the Association of Portland Cement Manufacturers, Atlantic City, N. J., June 15, 1904. Research Division, New York Testing Laboratory, Long Island City, N. Y., 1904. Pamphlet, 6x9 inches, 20 pp.

The author is first giving a brief review of the investigations made previously by others and theories deducted therefrom, which are confirmed by his own observations.

A description follows of synthetically prepared silicates and aluminates of various definite basicity, giving specific gravity, hydraulic properties and microscopical characteristics, which show that the author has given a great deal of time and systematic study to the subject.

After these preliminary studies, the author advances a most interesting and original theory of the constitution of cement clinker as a solid solution of the various constituents. He illustrates his theory by other simpler compounds which are more definitely known, and treats this very complex subject in a manner which gives the reader a clear conception of his ideas. He opens a very large field for investigation, which he later on covers to a large extent by further systematic experiments. The composition of "alite" seems definitely determined as being tricalcic, both in silicate and aluminate.

We do not, however, follow the author's argument when he says that clinker containing a large amount of alumina would require closer regulation than one low in alumina. It would seem, on the contrary, from the tables shown, that in order to obtain the same relative change in formula in the case of high alumina, a change of 4 per cent in lime must take place, against 2.1 per cent in the case of low alumina.

The author points out a number of valuable conclusions, which should be very useful to manufacturers of cement, and we hope that these investigations so ably outlined by the author will be continued, and that, as he suggests, the Association of Portland Cement Manufacturers may establish a laboratory for the prosecution of such work.

The pamphlet as a whole is by far the best and most thorough treatise on this subject ever published J. G. B.

Notes on Hydrology, and the Application of Its Laws to the Problem of Hydraulic Engineering. By Daniel W. Mead, Member American Soc. C. E., Professor of Hydraulic and Sanitary Engineering, University of Wisconsin, 1904. 202 pages, numerous tables, maps and diagrams,

This little volume is not only of considerable value to the engineering student, for whom it was probably prepared, but will be found very useful to the practicing hydraulic engineer, particularly for the reason that the information contained is very largely reduced to maps, tables and diagrams, carefully arranged, making it a work of ready reference. The diagrams are intelligible, well drawn, and bound in such manner as to be readily consulted. Each chapter is followed by an excellent bibliograph of the subject treated.

The author defines "hydrology" as the "Science of Water." "Hydrology in its broadest extent treats of the properties, laws and phenomena of water, of its physical, chemical and physiological relations, of its distribution and occurrence over the earth's surface and within the geological strata, and of its sanitary, agricultural and commercial relations."

The attempt has evidently been made to define the limits of the every-day problems of the hydraulic engineer without going into the ways and means of the development of water supplies and water powers.

The text matter is largely elementary, and is evidently intended for the student rather than the engineer; the chief value of the work to the engineer lies in the compilation of data relative to the physical properties of water, rainfall, and the disposal of the rainfall

Chapter II, treating of the physical properties of water, contains much condensed valuable information, and will be often consulted. The chapter contains tables of unit weight under various temperatures, the effect on weight of solutions, some characteristics of sediment bearing rivers, aqueous vapor, its characteristics, and energy, etc.

Chapter V treats of hydro-geology, that part of the geological science which has to do with the relations of water within the earth's structure. The hydrogeological maps of the Upper Mississippi Valley and the numerous well sections and characteristics in this region are particularly valuable.

Chapter VI.—Physiography of the United States contains a good map of relative elevations.

Chapter VII.—Rainfall is almost entirely diagramatic, the U. S. map showing distribution is good; other diagrams illustrate seasonal variations and intensity of rainfall in different localities.

Chapter VIII.—The disposal of the rainfall, contains an excellent map of the United States, showing relative run-off and also the relative evaporation in different sections. The subject of percolation, evaporation and water required by vegetation are here considered.

Chapter IX.—Stream Flow, contains many ingenious diagrams, showing the extreme variability of the problem. A table is given showing the drainage area, rainfall and run-off of over 300 water sheds, American and foreign. A diagram of maximum flood discharges in reference to drainage areas is excellent. Monthly and seasonal run-offs are also treated.

Chapters X and XI treat of ground water and surface water, respectively. A map is shown of the U. S. artesian area and diagram of the water fluctuations of the great lakes.

Short chapters follow, treating of the hydrometer of streams, the ice season, and the chemistry of natural water. In the latter chapter are given tables showing chemical analysis of representative waters.

The matter treated of in this book has heretofore been only partially covered in essh of numerous works upon water supply and water power. The idea of enclosing this information under one cover is believed to be most excellent, and it is hoped and believed that this collection of notes by one who has been for many years in active contact with these problems, will be extended and enlarged, forming a treatise upon a subject which, although of basic importance, has heretofore been only fragmentarily treated. C. B. B.

Cements, Mortars and Concretes—their Physical Properties. By Myron S. Falk, Ph.D., Columbia University, New York. M. C. Clark, New York. Cloth, 6x9 inches, 176 pages, including index. Many tables, diagrams and illustrations through the text. Price, $2.50.

This is a valuable contribution to American cement literature. It covers much of the recent data on the physical properties of concrete as determined by numerous laboratory tests by experts at home and abroad, which has heretofore been scattered through books and journals. It covers almost every kind of test to which concrete can be submitted to ascertain its identical properties as a material of construction.

The tensile and compressive strength tests are, as a rule, short time tests. The author (on page 133) adheres to the opinion that concrete does not appreciably gain in strength after three months. While this theory might obtain with an absolutely sound cement, in which the chemical affinities were perfectly balanced with the mixing, setting, hardening and ageing taking place at the most favorable temperature, the commercial Portland cements of today do not reach this ideal state of perfection. The finer a cement is ground, the sooner will it develop its ultimate strength. Eminent English cement experts adhere to the opinion that while a coarsely ground cement will not develop its ultimate strength as early as a finer ground cement, it will in time develop a much higher tensile and compressive strength than the finer ground material.

The text is clear, lucid, and to the point. The matter is well arranged and classified under numerous sub-heads, which are numbered, making the data convenient for ready reference. It also enables the reader to turn at once to the page for any particular data given in the text.

The book places before the reader the leading facts developed by the physical testing laboratories of the world in relation to the physical properties of cements, mortars and concrete.

The book should be in the hands of all engineers engaged in concrete construction. W. S.

Self-Propelled Vehicles. A practical treatise on the Theory, Construction, Operation, Care and Management of Automobiles. By James E. Homans. New York: Theo. Audel & Co. Second revised edition, 1904. Cloth, 5½x8¼ inches, 652 pages, including index; 461 illustrations, and portrait of Daimler, "Father of the Automobile." Price, $2.00.

This is a work intended to meet the needs of the automobile public, covering the most important features of that class of vehicles. It is gratifying to note that the author omits a great deal of historical information which might have been used to fill up space and be of interest only in showing what should not be done again. There are innumerable types of machines, novel in design, beautiful in outward appearance, but equipped with propelling machinery on the "freakish" order and utterly unfit for the severe service that automobiles are usually subjected to. The author has described several such machines, and has given them space which might well have been given to more up-to-date types, The automobile public is not an engineering class and does not design machines in whole or in part, and should be spared the danger of becoming "muddled" and unable to decide for itself what design of this or that part is most serviceable. It needs, rather, advice as to the proper manner of handling the machines it now has The author could better have served this purpose had he omitted some of the chapters on obsolete or little used types and given more attention to up-to-date machines. Particularly is this true of the chapters on electric vehicles and on storage batteries. Some of the deductions are not only unimportant but misleading, and should be reconsidered before the next edition is published. The chapters on gasoline machines are much more complete and would indicate that more importance had been attached to the discussion of that class of machines than to any other. This would naturally be the case, as the number and variety of gasoline machines are far in excess of other classes. A brief description is given of the engine and of special features of nearly all of the American-made cars and of the better known cars of foreign manufacture. One criticism which might be made on the manner of treating the subject throughout is the lack of the author's own opinion as to the relative merits of the various designs of parts which enter into the make-up of a self-propelled vehicle of any class

The book may be considered the most complete of its kind on sale, and while it is not all that could be desired to cover the needs of automobile users, it is well worth careful reading. E. L.

Reinforced Concrete. By A. W. Buell and C. S. Hill. New York: The Engineering News Publishing Co. Cloth, 6 x 9 in., pp. 434, with index, and 311 illustrations in the text. Price $5.00.

The growth in the application of reinforced concrete in the United States during the past few years has been very marked. This rapid growth has produced many conflicting opinions regarding the subject. Difference of opinion, however, leads to a more thorough investigation, with the result that the truth is more firmly established in the end.

In order that a subject may be understood, it is necessary that books be written on the subject. The treatise before us is the first work on reinforced concrete to appear in the United States. For sometime the need for literature on reinforced concrete has been greatly felt; this mode of construction is more discussed at present than ever before, so the advent of this book is all the more opportune, and it will be welcomed by engineers, designers, students and others.

From the preface we will quote as follows: "In preparing this book the authors have had in mind a treatise for designing and constructing engineers following American practice and governed by the conditions which prevail in America. Theoretical discussions have been omitted, and in their place have been supplied practical working formulas, examples of representative structures, and records of actual practice in the selection of materials and of methods of workmanship and construction."

The book comprises three divisions:

Part I, entitled Methods of Calculation, is written by A. W. Buel. Part II, Representative Structures, and Part III, Methods of Construction, are by C. S. Hill.

In Part I are given many practical formulas, covering the entire field of reinforced concrete. Under the head of beams, several of the leading formulas derived by prominent engineers are given. The results of several series of beam tests are also given, so that ample opportunity is afforded for comparing the theoretical and the practical phases of beam construction. In the chapter on arches, several practical examples are given illustrating the application of the formulas. This chapter cannot fail to interest many engineers who have to do with that most difficult application of reinforced concrete—the arch.

In Part II, structures in reinforced concrete, both in the United States and in Europe, are described. These examples embrace every class of structure that could have been built of steel, masonry, or timber. The great variety of examples cited show that reinforced concrete has a wider range of practical application than has any other material of construction. Examples of the smaller applications of reinforced concrete are not omitted.

In Part III, entitled Methods of Construction, are first described many of the symptoms of reinforced concrete in use in this country and Europe. Practical information regarding the handling of materials, methods of concreting, construction of falsework, etc., is given. One chapter is devoted to methods of facing and finishing exposed concrete surfaces.

In conclusion, it may be stated that the book is well written, the arrangement and paragraphing of subjects are easy to follow, and the index renders the volume a ready reference book. A. L.

Maxwell's Theory and Wireless Telegraphy. By Frederick K. Vreeland, New York. McGraw Publishing Co. Cloth, 6x8 inches, 255 pages, 145 illustrations in the text, and full index. Price $2.00.

To those of us who are not gifted with vigorous imagination it is sometimes a difficult matter to gain an adequate comprehension of electrical phenomena, especially when the action is of the complicated character of that which occurs in the production and propagation of Hertzian oscillations. Our ability to liken the flow of the electric current in a wire to that of water in a pipe is of considerable assistance in forming a conception of direct current phenomena; this similie fails, however, when we have to deal with alternating current effects, and new analogies are necessary to enable the mind to grasp the significance of the action.

Perhaps as clear and at the same time accurate a word picture as has ever been drawn of the modern conception of electrical phenomena as first expressed by Maxwell, is the classic essay of Poincare on Maxwell's Theory and Hertzian Oscillations, which first appeared in 1899; and in selecting this treatise as the foundation for his volume, Mr. Vreeland has chosen well. The translation has been well made, and the only defect which existed in Poincare's essay in its original form has been corrected by the addition of a number of illustrations which present with commendable clearness the mechanical analogues of the electrical forces, as described in the text. Little need be said of this essay, which constitutes the first division of the volume, as it is too well known and its merits too generally appreciated to require any extended mention. Its twelve chapters are devoted to a logical development of the theory establishing the relationship between light and electric waves, each step in the process being supported by experimental proof and illustrated by mechanical analogy. Mathematics is entirely eliminated and the whole matter is reduced to its simplest terms.

From the first conception by Maxwell of the true nature of the action involved in the propagation of electrical disturbances to the complete proof of this conception and the establishing beyond peradventure of the identity in kind between light waves and electric waves each stage in the advance is lucidly covered; the recognition of the necessity of producing alternating currents of extremely high frequency in order to obtain measurable displacement currents; the determination of the nature of the Leyden jar discharge, and the genesis of the oscillator as a means for the production of the required high frequency currents; the development of the resonator and the various devices for detecting and measuring the oscillatory currents set up in it; then, through the agency of the producing and detecting devices, the determination of the wave length of a disturbance propagated along a wire, the determination of the wave length of the disturbance in free air, and, by comparison of the two, the conclusive proof that the velocity of the light wave are the same; and finally the complete establishment of the truth of Maxwell's theory by the reproduction with electric waves of all the phenomena of optics. The chapter on the measurement of wave length and multiple resonance has a particular practical interest in connection with syntonic wireless telegraphy on account of the thoroughness with which it treats of the phenomenon of the production of complex waves in the oscillator and the selection by the resonator of that wave which corresponds to its own natural period.

Although Poincare's essay is only concerned with the scientific aspect of the actions of which it treats, it is well adapted to serve as a basis for the practical consideration of the subject which follows in the second part of the volume. This commences with a brief statement of the three methods of signaling through space without intervening conductors; namely, by electromagnetic induction, by electrostatic induction, and by electromagnetic waves. After a brief explanation of each, illustrated by well conceived mechanical analogies, and a reference to the most notable examples of the three methods, the attention is directed to the electromagnetic wave method, the development of which is taken up in detail, and traced through the early experiments of Hertz, Branly, Lodge and Marconi, through the period of crude, insensitive coherers, great capacity areas, reflectors and effective transmission over distances of not to exceed a few miles, to the advent of the grounded vertical antennæ of Popoff and Marconi and the extension of the range of signaling to hundreds and even thousands of miles, A great deal of stress is properly placed on the grounding of the oscillator as a means of increasing the range of transmission, and a chapter is devoted to a consideration of the character of the disturbance propagated under such conditions. The hypotheses, first, that the action is due to free waves in the ether exactly like those studied by Hertz, except with respect to their wave length; and second, that it is due to alternating currents flowing in and out of the antenna and transmitted by conduction through the earth or sea, are both discarded as being insufficient to explain the observed effects; while the now generally accepted view that the action depends upon etheric Hertzian waves guided upon the conducting surface that they traverse so as to follow the contour of the earth, is elaborated and shown to be entirely consistent, both with the observed effects and with the Faraday "tubes of force" and the Hertz electromagnetic wave conception of electric action.

The chapters on transmitting and receiving apparatus show that the author is in close touch with the situation, and is familiar with the practical requirements of the art. Wireless telegraphy has long since passed the stage of the old hammer-break induction coil and the single antenna, and the problems that now confront the workers in the field are those having to do with the production, control and radiation of such quantities of energy as to be entirely beyond the scope of the methods employed by the earlier investigators. The chapter on receiving apparatus describes a number of detectors typical of the various sorts of devices that have appeared, which the author has classified as microphonic, mechanical, thermal, electrolytic and magnetic receivers. It is to be noted that Mr. Vreeland lays claim to the development of that peculiarly sensitive and efficient receiving device, the electrolytic "barretter," which has heretofore generally been ascribed to Professor Fessenden, and which was also independently discovered by Schloemilch. The chapter on "Selective Signaling" is quite comprehensive, as befits a subject of so great practical importance, and is particularly well supplied with illustrations, including clearly presented circuit diagrams, curves and representations of mechanical analogues of the various arrangements for securing resonance and syntony.

On the whole, the matter in this volume is well selected, carefully digested, clearly and thoroughly illustrated, and arranged in a logical and orderly manner. The book well repays the reading. S.

THE ESTABLISHMENT OF AN ENGINEERING DIRECTORY.

As one of the functions of the Western Society of Engineers is to promote a feeling of comradeship between its members, and to render assistance to them in their professional work, the Board of Direction have decided to establish what for want of a better term, may be called an Engineering Directory. The object of this is to bring together those members who may be on the outlook for an engagement and those who desire the services of engineers. It is proposed to do this without cost to the members in the way of charges, fees, etc.

The name of the applicant for position will be kept privately by the Secretary and not given out, except as provided for in the rules, and every endeavor will be made not only to render real assistance to those members of the Western Society of Engineers who are out of employment, or who may be in search of more congenial positions, but to render such assistance in the right way.

Attention of employers of engineers, whether members or not, is also called to the exceptional value of this bureau to parties desiring engineering services of the highest order.

Rules to Govern the Conduct of this Directory.

First. Blank applications for employment will be given to any member of the Western Society of Engineers or forwarded to him on receipt of request, accompanied by a self-addressed stamped envelope.

Second. When returned to the Secretary, these applications shall be numbered for identification, and posted on a public file in the rooms of the Society. The name and address of applicant shall be kept on the detached coupon on a private file, numbered the same as the application, and will not be given out except to bona fide employers, and then only when in the judgment of the Secretary no confidence is violated in so doing.

Third. Applications from employers of engineers will be placed on a similar public file, and notifications will be sent to all applicants meeting the required conditions, or to any applicant specially designated by prospective employer.

Fourth. Applications, whether of employers or those seeking employment, shall be kept on file for the two calendar months succeeding the date of application, and then taken off and destroyed. A brief abstract of each applicaton, identified by number only, and stating character of position sought and salary expected, will be published in the JOURNAL. Any letters addressed to file numbers in care of the Secretary will be forwarded to destination.

Fifth. Applications may be kept on file for a longer period than two months if desired by the applicant, who shall notify the Secretary to this effect by postal card or otherwise. Applicants are also requested to notify the Secretary promptly when the application is to be taken off the file.

It is to be hoped that this arrangement of applications, etc., filed at the offices of the Society, will result in benefit to those members who are seeking a professional engagement.

BY ORDER OF THE BOARD OF DIRECTION.

J. H. WARDER, Secretary.

August 5, 1902.

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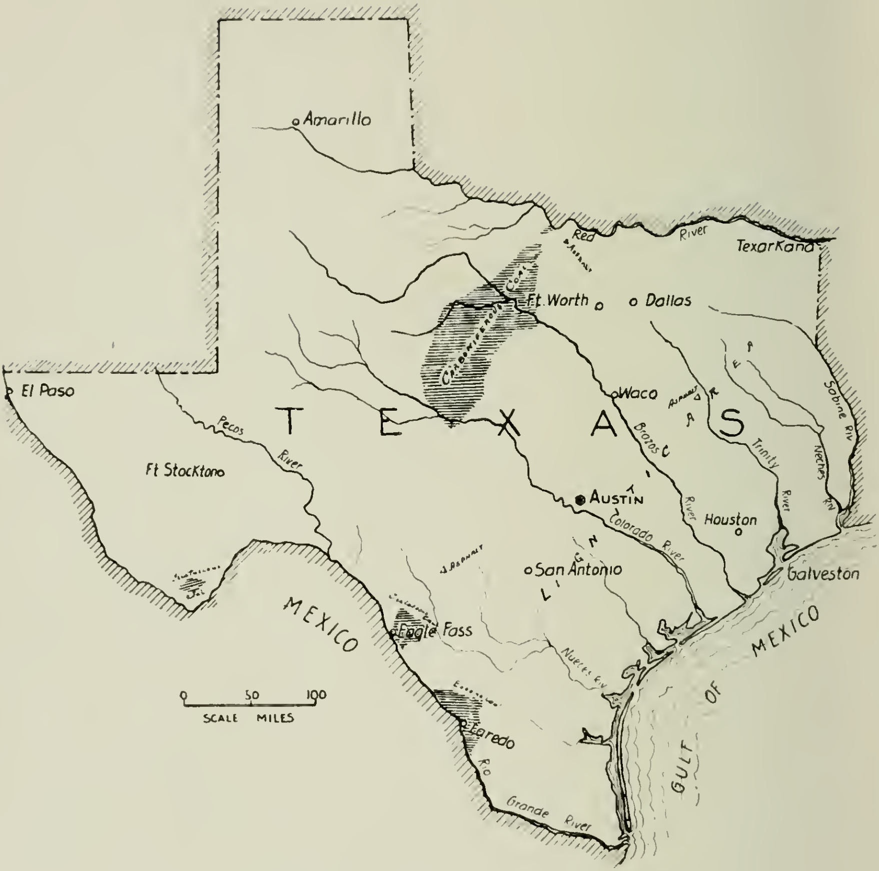

LOCATION OF SOME OF THE COAL DEPOSITS OF TEXAS.

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THE COAL, LIGNITE AND ASPHALT ROCKS OF TEXAS.

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Presented May 4, 1904.

When I was requested to address this distinguished body of engineers on the subject of "The Texas Hydrocarbons," I accepted with the mental reservation that in the time during which I should tax your patience I could touch the matter only in high places. Any one of the so-called hydrocarbons in Texas demands and of right should have an entire treatise, whether we discuss coal, or lignite, or asphalt, or natural gas or crude petroleum. The scientific and practical sides of any of these, calls for a great deal more information than I possess. But I do not know that there was ever a man from Texas, whether indigenous or transplanted, who did not consider himself equal to almost any task. It is characteristic of that vast expanse, from Texarkana to El Paso and from Texline to Sabine Pass, that it forces one to look at things in a large way, and the people who have made Texas what it is to-day may be excused for holding that they can do any thing, from riding a bucking broncho without either saddle or bridle to discussing before men much better informed, any subject that may be proposed.

It has been my fortune during the last three years to have had charge of the mineral survey of the State, administered by the Board of Regents of the University. This survey took the place of the former geological survey which was established in 1888 and came to an end in 1892, after having accomplished a great deal of valuable work. But like some other good things it failed to receive proper financial support at the hands of the legislature and was compelled to cease its operations. From 1892 until the spring of 1901 there was no State survey of any kind, nor any authorized bureau of information concerning the mineral resources of the State. In the latter year, however, an earnest effort was made to establish such a bureau as would meet the increasing demand for accurate data. We were greatly helped in this movement by the discovery of oil in vast quantities at Spindle Top, a few miles south of Beaumont, Jefferson county. The first gusher at this now world-famous spot came in on the 10th of January, 1901, and I am proud to say that my old personal friend, A. F. Lucas, was the fortunate discoverer.

We began work with a small appropriation, $10,000 a year for each of two years, and were able at the following meeting of the legislature to secure an increase to $15,000 a year, there being practically no opposition in either branch of the law-making body. It is self-evident that $10,000 or even $15,000 a year spread over 265,000 square miles of territory, much of it from 50 to 100 miles from the nearest railroad, would not be sufficient for an examination of the entire State, nor have we attempted this at all. What we have tried to do is to study a few of the more pressing problems and to issue special bulletins dealing with them. During the last two and a half years we have published bulletins on Texas Petroleum; Sulphur, Oil and Quicksilver in trans-Pecos, Texas; Coal, Lignite and Asphalt Rocks; The Quicksilver Deposits at Terlingua, Brewster County; The Minerals and Mineral Localities of Texas; The Texas Mining Law and Tables of Magnetic Declination, these last being taken from the reports of the United States Coast and Geodetic Survey; and A Report of Progress for the Year 1903. Inclusive of the special topographic maps, prepared for the survey by the United States Geological Survey, under a plan of co-operation, we have printed and distributed 41,000 copies of our bulletins. They have been so kindly received that all of the early editions have long since been exhausted.

Mention is made of this matter, not for the purpose of self-aggrandizement, but simply to inform this society of what we have attempted to do in the way of calling attention to the resources of Texas. Some of these subjects had been discussed by the former survey and Mr. E. T. Dumble, formerly State Geologist, in his publication entitled "Brown Coal and Lignite, 1892" gave evidence of having studied this important question thoroughly.

The subject divides itself naturally under three main heads. Thus we have solid hydrocarbons, liquid hydrocarbons and gaseous hydrocarbons. Similarly the solid hydrocarbons are grouped under three heads, coal, lignite (including brown coal) and asphalt, or bitumen. Under the liquid hydrocarbons we have the several varieties of crude petroleum, all classed, however, under the general term crude oil, and liquid bitumen. Under the heading gaseous hydrocarbons we have only one, natural gas, the exhalations of marsh gas from swamps, etc., not being of commercial importance.

SOLID HYDROCARBONS.

Coal, lignite and asphalt or bitumen.

The coal of Texas is bituminous and semi-bituminous, for the most part showing feeble coking qualities, although there are some seams from which a fair coke could be made by washing and improved coking processes. So far as known at present we have no large seams of coking coal, nor any seams of coal that would yield good coke without preliminary treatment.

The production of all kinds of coal, including lignite, is about one million tons a year, an amount which falls far short of supplying current demands, the remainder being brought in from Indian Territory, Alabama, Arkansas and New Mexico. With the exception of works of the American Refining Company, at El Paso, there is not a great consumption of coke within the State. There are no iron furnaces using coke, the production of iron being limited to charcoal iron, at Rusk, Cherokee county. If a fair coking coal could be found it might be feasible to produce high grade Bessemer iron from the fine ores of Llano county, as also to enlarge the production from the brown ores of northeast Texas. In an address delivered before the Engineers' Society of Western Pennsylvania, March, 1902.* I discussed the iron resources of Texas at some length. As the situation has not changed with respect to the utilization of native materials it is not necessary to add to what was then said. The matter is briefly referred to now, because the use of bituminous coal for coke making naturally falls under this head.

For commercial purposes the coal and lignite areas may be considered under three divisions:

The lignites of Eocene Age, in Eastern and Southern Texas.

The coal and lignite of Cretaceous Age, in Southern Texas.

"The coal of Carboniferous Age, in Central and Northern Texas.

There are some seventy counties in Texas which contain beds of lignite, the thickness ranging from four feet, as at the Glenn-Belto mines, Bastrop county: to ten feet, as at the mines of the Central Texas Mining, Manufacturing and Land Company, Calvert, Robertson county. The depth of the workings below the surface varies from thirty-five feet, as near Lovelady, Houston county, to ninety-six feet, as in one of the mines near Rockdale, Milam county. The strata above the lignite are clays and more or less consolidated sands, but little timbering is to be seen and the ventilation is mostly by air shaft. Few accidents are recorded. There is no State inspection of coal or lignite mines, each operator securing the health and safety of the miners as best he may. In some parts of the lignite area considerable depressions may be observed on the surface, due to falls of the roof after the removal of the lignite. Of roof in the ordinary acceptation of the term there is none, the lignite being frequently mined directly from under a bed of sandy clay without stability.

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* Proceedings of the Engineers' Society of Western Pennsylvania, Vol. XIX, p. 64.

Following upon the discovery of the Beaumont oil field, early in 1901, there was a feeling that the end of lignite mining was plainly in view. It was held by many operators that no head-way could be made against cheap fuel oil. So strong did this feeling become that in the fall of 1901 almost every lignite mine in the State had closed down, or was running merely to fill out some special contract. But these fears proved to be without practical foundation. The days of ten cent oil gave place to twenty cent oil, then to thirty cent oil, then to forty cent oil, then to fifty cent oil and the lignite mines again came into use. There is a point at which fuel oil, unless used in large and regular amounts, has no real economy over solid fuel. I do not now care to enter upon a discussion of where this point is, its location depends on a variety of conditions, but that it has a real existence is shown by the history of fuel consumption in Texas during the last two and a half years. That there is room for both no one can deny, as no one can deny the assertion that fuel oil is not of universal application. A year after the discovery of the supplies of fuel oil at Beaumont good lignite was selling F. O. B. mines for 50 cents a ton, and I understand that some contracts were made at prices even lower than this. The present price varies from 55 cents to 70 cents F. O. B. mines. The cost of digging lignite ranges within comparatively wide limits; i. e., from 25 cents to nearly 60 cents a ton.

The freight charges on lignite and lignite briquettes are much less than on coal and coke. Supposing that but little coal or lignite of domestic production is used at a greater distance than 200 miles from the mines, except for railroad purposes, and I believe that this is well within the facts, then a comparison of the rates fixed by the Texas Railroad Commission might not be out of place here. Two rates are fixed by this Commission, No. 1 applying to such shipments as are to be transported over a single line of railroad or over two or more lines under the same management and control, and No. 2 applying to joint rates on shipments to be transported over two or more lines which are not under the same management and control.

The rates for distances up to 200 miles are as follows:

FREIGHT RATES ON SOFT COAL (EXCEPT SLACK), SMITHING COAL, COKE AND LIGNITE ON A TON OF 2,000 POUNDS.

	—Coal.—		—Lignite.—	
Distances, miles—	No 1. Cents.	No. 2. Cents.	No. 1. Cents.	No. 2. Cents.
30 and less	55	70	32	47
40 and over 30	60	75	35	50
50 and over 40	65	80	40	55
60 and over 50	70	85	44	59
70 and over 60	75	90	48	63
80 and over 70	80	95	53	68
90 and over 80	85	100	57	72
100 and over 90	90	105	60	75
110 and over 100	95	110	63	78
120 and over 110	100	115	66	81
130 and over 120	105	120	69	84
140 and over 130	110	125	72	87
150 and over 140	115	130	76	91
160 and over 150	120	135	79	94
170 and over 160	125	135	82	97
180 and over 170	130	140	85	100
190 and over 180	135	145	88	103
200 and over 190	140	150	91	106

Note—The minimum weight of each car load is 20 (twenty) tons; provided, that when the actual weight of a shipment contained in a car loaded to its full capacity shall be less than 20 tons, then the actual weight of such shipment shall be charged at the rate per ton applicable under this tariff.

Without considering the exceptions under this tariff an inspection of the table will show that lignite is a favored commodity. It is protected by reduced freight charges and this protection increases with increase of distance shipped. Thus, if a car of soft coal is shipped 100 miles and over 90 miles, under the No. 1 rate the cost per ton is 90 cents, the charge for lignite under similar conditions, is 60 cents. On a car load of 20 tons the total difference in favor of lignite is $6.00. If a car of soft coal is shipped 200 miles and over 190, under rate No. 1, the cost per ton is $1.40; the cost of lignite, under similar conditions, is 91 cents. To ship a car of soft coal 200 miles and over 190 miles costs $28.00, but the same car of lignite costs $18.20, the difference in favor of lignite being $9.80.

For the first 100 miles the freight charge on coal is $18.00 per car and for the second 100 miles it is $10.00, making the cost for the 200 miles $28.00. For the first 100 miles the freight charge on lignite is $12.00 per car and for the second 100 miles $6.20, making the cost for the 200 miles $18.20. These important differences as between coal and lignite were established for the purpose of promoting the mining and use of lignite, of which we have in Texas very large supplies, much larger than the supplies of soft coal. It was felt that some adequate protection should be afforded a fuel which was somewhat handicapped in the first instance by being less valuable and in the second by its deteriorating in storage. In a measure, it is a sort of State protection accorded an article produced within the State and one upon whose development and use depend the industrial progress of the State. In theory this might militate against the larger use of soft coal which is also mined in the State, but in actual practice this does not appear to be the case. Probably nine-tenths of the soft coal mined is taken by railroads for their own use and thus does not come into active competition with lignite. The composition of lignite has received considerable attention at the hands of this survey. In 1901 and 1902 we made careful measurements at the 15 mines that were worked, determining the thickness of the seams, etc. Samples were drawn in person and proximate and ultimate analysis made in great detail. When the samples were taken at the mines they were enclosed in tight tin cans, so that no loss of moisture could take place prior to the analysis. All of the results were published in our Bulletin No. 3, May, 1902. From these analysis it appears that the average composition of Texas lignites is as follows:

AVERAGE COMPOSITION OF TEXAS LIGNITES.

	—Prox. analysis.—	
	As mined.	Dry basis.
Moisture	33.37 %	.....
Vol. and combust	40.39	60.61 %
Fixed carbon	17.24	25.88
Ash	9.00	13.51
Sulphur	1.12	1.68
Sp. grav., dry	1.35	......
B. T. U.	7,614	11,427
	—Ultimate analysis.—	
	As mined.	Dry basis.
Carbon	40.13 %	60.23 %
Hydrogen	3.03	4.55
Oxygen	12.29	18.45
Nitrogen	1.18	1.47

The average weight of a cubic foot of dry lignite is 83.10 pounds.

In their natural condition, as mined, the Texas lignites show the following range of composition:

Moisture from 29.07 to 36.16 per cent.

Volatile and combustible matter from 28.96 to 51.00 per cent.

Fixed carbon from 3.41 to 24.47 per cent.

Ash from 4.87 to 17.60 per cent.

Sulphur from 0.47 to 3.29 per cent.

Heat value, B. T. U., from 6,474 to 8,053.

Weight per cubic foot from 53.5 pounds to 69.7 pounds.

Lignite dries very rapidly when exposed to ordinary Texas weather, but on drying it manifests a decided tendency to fall to pieces and this may continue until the great part of a car-load has been reduced in size to fragments of one or two cubic inches. However, not all lignites exhibit this in the same degree, some are harder and more dense than others and keep better in storage.

It may be of interest to give a statement regarding the average composition of the ash of Texas lignites, which is as follows:

	Per cent.
Silica	38.57
Alumina	20.67
Oxide of iron	9.04
Lime	16.84
Magnesia	0.94
Oxide of manganese	0.81
Sulphuric acid (combined)	12.90

After burning until all of the combustible matter has been removed some of these lignites still yield carbonic acid, in one case as much as 9.80 per cent. The range of composition of the ash of these lignites is as follows:

Silica from 21.64 to 63.40 per cent.
Alumina from 11.94 to 34.26 per cent.
Oxide of iron from 2.02 to 24.85 per cent.
Lime from none to 38.17 per cent.
Magnesia from a trace to 4.36 per cent.
Oxide of Manganese from a trace to 3.32 per cent.
Sulphuric acid (combined) from 3.53 to 20.92 per cent.

Some years ago an effort was made at Rockdale, Milam county, to briquette the lignite of that locality and costly machinery was introduced. The time was not propitious and the enterprise soon languished. Perhaps one reason for the failure was the lack, at that time, of a good, cheap binder. Coal tar was used but was not satisfactory. The briquettes were of good quality but they could not be sold at sufficiently low cost to command a regular market. Now that petroleum residues and residues from sugar works can be obtained, as well as coal tar, it would appear that there was some hope of a profitable business. But the low price of lignite may continue to interfere. Some recent contracts have been made at 57½ cents per ton, F. O. B. mines, and it is reported that even lower prices can be obtained. With ordinary, good lignite at 57½ cents a ton it is likely that the manufacturer of briquettes would have his work cut out for him, unless he was exceptionally favored by cheap materials and low transportation charges. Nothing is now being done in this direction, although the improvements in briquetting processes and in binders, made during the last ten years, might enable one to do now what was found to be impracticable in 1894.

There has been some discussion of the establishment of a briquetting plant at the World's Fair, St. Louis, to work on a commercial scale, testing the different kinds of lignite, dryers, binders, etc., and the project has assumed tangible form. If undertaken at all it will have to be at the expense of the manufacturers of the machinery involved, assisted by the mine owners who would furnish the lignite at cost, or even donated it.

In connection with the work of the University of Texas Mineral Survey we propose to erect a small testing plant in Austin this coming fall or winter for the purpose of giving the lignite miners an opportunity of experimenting in the manufacture of briquettes. We hope to try different plans for drying the lignite, of crushing it and incorporating the binder. The subject is of considerable importance to us in Texas, for it is to be doubted if any other State has so large deposits of good lignite as our State has. It may be that briquettes, in connection with smoke-preventing devices, will aid us in solving the all important fuel question in Texas. I say, smoke-preventing devices, for it is easier and more economical to prevent smoke than to consume it after it has once been allowed to form. Automatic stoking may be looked to as one way out of the difficulty. At many places in the State lignite is holding its own against fuel oil now and it is thought that with firm briquettes and smoke prevention the growth of the industry could be greatly enlarged.

The coal in southern Texas which is now of commercial importance is in the counties of Webb and Maverick, the former being known as the Laredo and the latter as the Eagle Pass Field. These two counties are on the Rio Grande and the coal there is connected with the extension of the deposits into Mexico.

In its natural condition, as mined, the Laredo coal has the following range of composition:

Moisture, from 1.00 to 4.09 per cent.
Volatile and Combustible Matter from 47.95 to 51.87 per cent
Fixed Carbon, from 36.46 to 38.89 per cent.
Ash, from 9.07 to 11.09 per cent.
Sulphur, from 2.09 to 2.45 per cent.
Heating value, B. T. U., from 11,052 to 12,806.
Carbon from 66.65 to 66.70.
Hydrogen, from 5.35 to 5.65.
Oxygen from 7.46 to 10.85.
Nitrogen from 1.47 to 3.62.
Weight per cubic foot, from 77.4 pounds to 79.6 pounds.

The range of composition of the ash of the Laredo coal is as follows:

Silica, from 42.08 to 44.48 per cent.

Alumina, from 24.79 to 35.79 per cent.

Oxide of iron, from 14.74 to 23.03 per cent.

Lime, from 2.56 to 4.69 per cent.

Magnesia, trace.

Oxide of manganese, from a trace to 1.75 per cent.

Sulphuric acid (combined) from 3.52 to 4.57 per cent.

The Laredo coal is in good demand along the line of the International & Great Northern Ry. and is of fair quality. Two sections of the seams in this field may be given: the one section shows, from the roof down, one foot and two inches of coal, then two and a half inches of bone, and then another one foot and two inches of coal, the total thickness of the coal being two feet and four inches with a parting of bone two and a half inches thick.

The other section shows, from the roof down, one foot and one inch of coal, one inch of slate and another one foot and one inch of coal, the total thickness of the coal being two feet and two inches with a one inch parting. The seams are reached by means of shallow shafts, 50 to 150 feet in depth according to circumstances. There is one railroad into the field, the International & Great Northern, connecting with the Mexican National at Laredo. The present price of coal, F. O. B. mines is $1.50 to $2.00.

The other coal field in southern Texas is in Maverick county, near Eagle Pass, where the Southern Pacific Ry. makes connection with the Mexican International.

The range of composition of the Maverick (Eagle Pass) coal is as follows:

Moisture, from 6.91 to 9.40 per cent.

Volatile and Combustible Matter, from 33.08 to 38.16 per cent.

Fixed Carbon, from 36.82 to 40.09 per cent.

Ash, from 17.43 to 18.11 per cent.

Sulphur, from 1.28 to 1.96 per cent.

Heating value, B. T. U., from 11,149 to 11,472.

Weight of a cubic foot, from 79.6 pounds to 95.6 pounds.

Carbon, from 58.85 to 62.55 per cent.

Hydrogen, from 4.14 to 4.53. "

Oxygen, from 8.07 to 9.60. "

Nitrogen, from 0.78 to 1.63. "

The range of composition of the ash of these coals is as follows:

Silica, from 62.72 to 65.34 per cent.

Alumina, from 24.56 to 30.04 per cent.

Oxide of iron from 3.38 to 9.84 per cent.

Lime from 0.64 to 0.91 per cent.

Magnesia, from 0.36 to 0.70 per cent.

Sulphuric acid (combined) from a trace to 0.80 per cent.

The coal is reached at a depth of about 210 feet being overlaid by clays, sandstones and limestones. It is customary, in some parts of the field to leave a foot of coal for roof. Two sections may be given.

	Feet.	Inches.
Coal left for roof	1	0
Slaty clay	0	2
Coal	1	4
Slaty clay	0	2
Coal	1	4
White fire clay and bone	1	6
Coal	1	4
Clay	Floor.	

Section two—	Feet.	Inches.
Bone	Roof.	
Coal	0	11½
Bone	1	0
Coal	1	3
Bitum. matter mixed with clay	0	2
Impure coal	0	6
Bituminous shale	2	0
Coal	0	6
Clay	Floor.	

The first section shows four feet of coal in three benches, the second shows two feet and nine inches in three benches. In other words the coal in the Eagle Pass field may run to four feet, but is apt to be not thicker than one foot and four inches in any one bench.

There is a possibility of finding coking coal in this field, some samples having been examined that would yield a fair coke if washed. It is feasible to extend coal mining operations in this field with a fair prospect of success. The field lies within 30 to 35 miles from the main line of the Southern Pacific Ry., and a branch of this road connects the main line at Spofford Junction with the Mexican International at Eagle Pass.

The two coal fields in southern Texas, thus briefly described, are the only coal areas in that part of the State. The coal is of cretaceous and tertiary age, has not yet been turned into coke on a commercial scale, but makes a fair steam and domestic fuel. One could enter, somewhat more at length, upon a discussion of the geology of these fields, but such is not the purpose of this paper, but confine it to the commercial possibilities. The exact area of these fields have not yet been determined, but it is likely that either field could yield considerable coal for many years.

COALS OF THE CARBONIFEROUS FORMATION.

The carboniferous formation in Texas that is productive of coal, occupies a pear-shaped area extending from about Brady, McCulloch county, in a northeasterly direction to the Red River. Its eastern line is about forty miles west of Fort Worth. From east to west its maximum width is about 100 miles, while from southwest to northeast its length is about 200 miles. It has been thought by some observers that the available coal area, within the carboniferous limits is about 2,700 square miles, but it is not yet known how much of this estimated area is underlaid by workable coal. The Gulf, Colorado & Santa Fe Ry. traverses the southern part of the field, from Brownwood to Ballinger; the Texas Central Ry. runs through the heart of it, by way of Dublin and Cisco; the Texas & Pacific Ry. cuts it in two, from Weatherford to Abilene; the Rock Island comes in from the north and now has progressed as far south as Graham, Young county; the Fort Worth & Denver Ry. crosses the northern part of the area in Montague and Clay counties, while still further north the Missouri, Kansas & Texas Ry. crosses it, south of Red River.

Active mining operations are carried on in the counties of Erath, Palo Pinto, Eastland, Parker and Wise, the total production of these counties being nearly one-half of the total coal output of the State.

In character the coal is bituminous and some seams would yield a fair coke. Some years ago an attempt was made to secure some of the coke trade at El Paso and a few bee-hive ovens were constructed. But the coke was not of good quality and the enterprise soon came to an end. It is, however, probable that a fair coke could be made if the coal was washed, this having been neglected in the former attempt. The seams are reached by shafts varying in depth from 140 to 235 feet. Two sections of the seams may be given:

	Feet.	Inches.
Black draw slate	0	8
Coal	0	2
Dark clay	0	$1\frac{1}{4}$
Coal	0	$2\frac{3}{4}$

Dark clay	0	1
Coal	1	7
Bone	0	2
Coal	0	3
Fire clay	0	4

SECTION TWO.

	Feet.	Inches.
Slaty clay	Roof.	
Coal	0	8¼
Slaty clay	0	¾
Coal	0	6½
Slaty clay	0	¼
Coal	1	0
Clay	Floor.	

Each of these sections shows about 26 inches of coal, with three partings in the first and two in the second. It is by no means certain that the best coals in this area have been opened and there are possibilities in Stephens county yet unregarded. On the Clear Fork of the Brazos River, 25 miles from the line of the Rock Island at Graham, and about the same distance from the line of the Texas Central at Albany, there are seams of coal which have been neglected, although the quality of the coal appears to be much better than at any point where operations are now conducted. On the Albert Sidney Johnston Survey, near Crystal Falls, Stephens county, there is reported a seam of good coal which was used many years ago at old Fort Belknap. Nothing has been done towards its development, however, the distance from rail acting as a deterrent circumstance. And yet this part of the field can be easily reached, either from the terminus of the Rock Island at Graham, or from the Texas Central at Albany, the latter route being, perhaps, the better of the two.

Railroads must have coal. Out of a total production of about 400,000 tons at one place along its line the Texas & Pacific takes about 360,000 tons a year, leaving only about 40,000 tons to be marketed outside. The Gulf, Colorado & Santa Fe, the Texas Central, the Rock Island, the Fort Worth & Denver, the Missouri, Kansas & Texas Railroads, all penetrate the coal fields under consideration. They need a great deal of coal themselves, and they go into the most populous and progressive portions of the State.

Of these roads the only one that reaches the Indian Territory coal fields, from which the largest supply of outside coal is obtained, is the M. K. & T. There is a railroad now building through

Texas, the Kansas City, Mexico & Orient, familiarly known as the Orient Road. It passes to the west of the carboniferous area in Texas and does not touch it at any point. For 1,500 miles this road does not touch any coal field, for after coming out of Oklahoma its next coal is away below the Rio Grande, in Mexico. Some day, and it may not be so far away, the Texas Central will build to a connection with the Orient road, beyond Stamford, in order to supply that road with coal. The undeveloped coal resources of the carboniferous area in Texas will be drawn upon to a greater and greater extent and new fields will be called upon for their quota of fuel. An extension of the Rock Island road from Graham to Cisco would carry that road through the heart of Stephens county, which contains today what may prove to be the best coal field in Texas.

In Texas we do not expect to open great seams of coal such as are to be found in more favored localities. We do not ask for four, five and six foot seams, knowing well that if we should they would not be forthcoming. With us coal is coal and a three-foot seam, or even one of thirty inches is thankfully received. Among the things which we have set before us in connection with the present mineral survey is a detailed study of the carboniferous area in Texas, its limitations, workable seams of coal, quality of the coal, transportation questions, etc. We hope to enter upon that task this year and to pursue it until we can know a great deal more than is known at present.

The range of composition of the carboniferous coals in Texas is as follows:

Moisture	From	4.00	to	13.44	per cent
Volatile and Combustible Matter	“	29.17	“	35.66	“ “
Fixed carbon	“	36.37	“	49.17	“ “
Ash	“	9.71	“	24.76	“ “
Sulphur	“	1.51	“	4.76	“ “
Heating value, B. T. U.	“	9,609	“	12,264	“ “

The weight per cubic foot varies from 65.2 to 89.9 pounds.

Perhaps a fairer way of stating the composition of these coals is to give the average composition as determined by the analyses of thirteen samples taken at all the mines. This average is as follows:

Average proximate composition of the carboniferous coals in Texas:

Moisture	7.84	per cent.
Volatile and Combustible Matter	32.62	“
Fixed Carbon	42.91	“
Ash	16.62	“
Sulphur	2.26	“

Heating value, B. T. U.	11,195
Weight per cubic foot	81.3 pounds.

Average ultimate composition of the carboniferous coals in Texas:

Moisture	7.84	per cent.
Carbon	60.00	"
Hydrogen	5.00	"
Oxygen	8.50	"
Nitrogen	2.00	"
Ash	16.62	"
Sulphur	2.26	"

The range of composition of the ash of the carboniferous coals in Texas is as follows:

Silica, from	29.14	to	54.34	per cent.
Alumina, from	13.10	"	43.92	"
Oxide of iron, from....	3.68	"	28.02	"
Lime, from	trace	"	22.02	"
Magnesia, from	trace	"	1.91	"
Oxide of manganese....	trace			
Sulphuric acid, combined	trace	"	15.00	"

The average composition of the ash is as follows:

Silica	43.61	per cent.
Alumina	25.08	"
Oxide of iron	17.14	"
Oxide of manganese	trace	
Lime	7.13	"
Magnesia	0.87	"
Sulphuric acid, combined.........	5.00	"

With this necessarily brief discussion of the coals and lignites of the State we must pass on to the next subject to demand attention, which shall be made as brief as possible, is that of the

ASPHALT ROCKS, OR BITUMINOUS SANDSTONES AND LIMESTONES.

These may be grouped, as indicated, in two divisions, the bituminous sandstones and the bituminous limestones.

The bituminous sandstones are found in the counties of Montague, Cooke, Anderson, Tyler, Jasper, Hardin, Nacogdoches and San Augustine. They belong to the cretaceous and to the marine eocene. Their composition is as follows:

Locality—	Asphaltene.	Petrolene.	Total bitumen.	Mineral matter.	Sulphur.	
Montague County	3.60	7.00	10.60	89.20	0.20	per cent
Cooke County	2.46	10.18	12.64	87.36	0.50	" "
Anderson County	11.25	12.09	23.34	76.71	0.43	" "
Jasper County	7.12	20.14	27.26	72.74	0.15	" "
Uvalde County	5.08	5.12	10.20	88.70	0.80	" "

Some of the Uvalde county rocks carry bitumen up to 15.60 per cent. The extent of these several deposits is quite sufficient for all practical purposes, but the material has not been much used for paving. Some sidewalks were laid in St. Joe, Montague county, of the local rock, and the Anderson county material has been used on the streets in Palestine with good results.

The bituminous limestones are found in the counties of Burnet and Uvalde. Their composition is as follows:

Locality—	Asphaltene.	Petrolene.	Total bitumen.	Carb. lime.	Silic. matter.	Sulphur.
Uvalde County	7.00	7.00	14.00	83.00	2.00	to .17%
Burnet County	7.76	6.75	14.51	84.00	1.50	to 0.22%

The Burnet county stone has not been utilized, although it is within two miles of the railroad and lies favorably for cheap mining.

The Uvalde county bituminous limestone has been more extensively used than all of the other bituminous rocks in the State combined. Works of considerable size have been erected at Carbonville, and for some years past operations have been continued intermittently. The works originally designed for the extraction of the bitumen with naphtha, and the first shipments of what was termed "litho-carbon" were made in 1894-95. Between 1895 and 1899 the naphtha treatment was suspended and since 1900 no bitumen has been extracted. The total production of naphtha-extracted bitumen at these works is about 2,043 tons. Since 1900 the business has been entirely confined to the shipment of crude and crushed rock for paving purposes, the total production having been about 35,000 tons. The rock has been used in San Antonio, Houston, Waco, Shreveport, etc., and has, I believe, given good satisfaction when properly laid. For paving purposes it is doubtful if any better bituminous limestone can be found anywhere than the Uvalde rock. It can not be shipped far, and for this reason it has not come as much into use as its high grade would warrant. But as the Texas cities and towns increase in population and wealth it is fair to assume that this excellent stone will be largely employed for paving.

There are extensive deposits of this stone, as also of the bituminous sandstone and a kind of stone half way in composition between these, in Uvalde county, easily accessible from the Southern Pacific Ry. The deposit of bituminous limestone at Carbonville is known to be more than twenty feet in thickness, overlaid by from two to four feet of limestone. The deposit is of cretaceous age, the bitumen impregnating what is known as the Anachacho limestone. The region has been disturbed by intrusion of igneous rocks, among which may be mentioned a nepheline-melilite-basalt and a plagioclase basalt. The impregnation of the porous limestone with bitumen has been attributed, in some measure, to the influence of these igneous intrusions. Bituminous matter in sandstones and shales and clays is closely associated with the occurrence of cinnabar, at Terlingua, Brewster county, where igneous rocks have also come into the geology of the district. In the early history of that quicksilver district the iron retorts used for distilling the metal also yielded oil and gas. Bitumen is by no means a rare constituent of the quicksilver ores in Brewster county.

In speaking of the uses to which the asphalt rocks of the State may be put I am fully aware of the fact that by far the greater mileage of paving in the United States has been laid of sheet asphalt and that the tendency seems to be toward this rather than towards rock asphalts. And yet where the rock asphalt has been laid under proper conditions, with due regard to its preliminary treatment before going into the street, experience has shown that in competition with sheet asphalt it has a fair fighting ground. I suppose that Buffalo, N. Y., has a greater mileage of rock asphalt streets than any other American city. Kentucky bituminous sandstone has been used there with good success. It is certainly true that the distances over which the rock asphalts have to be carried from quarry to points of consumption have operated to its disadvantage. It is self-evident that such a material will not stand long hauls. Its chief use must be local, so to speak, and for the development of the Texas rocks we must wait for the inevitable increase of population and wealth. That State is growing at a tremendous rate and the impetus it has acquired will carry it on in spite of the cotton-boll weevil, occasional destructive storms, drouth and the low price of cattle. It has now more railroad mileage than any other state in the Union and the main trunk lines are sending out feeders in every direction.

The asphalt rocks will come into use for paving purposes. I do not think that they offer many inducements for the extraction of bitumen on a large scale. The practical difficulties opposed to this are very great and they do not seem to appeal to that sentiment of making a dollar earn two that is so potent in this age. In the meantime the deposits will not run away. The temperature in certain parts of Texas during the summer is high enough to cause some of the bitumen to exude from the rocks, it is true, but there is plenty more and what is lost in this way is of small moment. But the equable temperature for the greater part of the year is a distinct gain for asphalt pavements. They may and they do soften under the heat, but they do not freeze and disintegrate.

In addition to the preceding there are two kinds of solid hydrocarbons which possess merely a scientific interest. The first of these is what is known as "Sea Wax." It is a black substance often to be picked up along the Gulf coast from Sabine to Brownsville. This material has been investigated by Dr. A. L. Metz, Tulane University, New Orleans. The material he examined came from the coast of Jefferson county. It contained 98.24 per cent of bitumen, 1.44 per cent of organic matter other than bitumen, and 0.32 per cent of mineral matter. There were no soluble salts in it nor any sulphur. The bitumen extracted by means of carbon bisulphide yielded 5.30 per cent of a volatile, inflammable oil at 260 degrees F. It also yielded 83.27 per cent of petrolene, 10.17 per cent of asphaltene, and 1.26 per cent of retene. Pieces of this substance of some size have been obtained from time to time along the coast, but it does not appear to be of commercial importance. Another interesting substance is obtained from along the coast near Rockport, Refugio county. It is a paraffin so pure as to excite suspicion of its natural origin. And yet, if human testimony can be believed, it is of natural origin. It has been picked up along the coast and particularly along the shore opposite St. Joseph's Island. Old fishermen assert that for many years they have been able to pick up masses of this substance, and I have myself seen one piece that weighed nearly twenty pounds. It is translucent, yellowish in color, melts easily in the sun, has a somewhat greasy feel and is beyond question a variety of paraffin. Whence it comes I am unable to say. That such a material should be obtained from crude oil by any known natural methods seems improbable, and yet I am satisfied, from the evidence, that it has appeared at one locality for thirty or forty years. It is not of commercial importance, but has occasioned considerable speculation among the few scientific men who have visited that portion of the gulf coast.

NATURAL GAS.

Natural gas is the only one of the gaseous hydrocarbons that need be considered. This substance is of wide distribution in Texas, occurring in all of the known oil fields and in some localities where oil has not been found in commercial quantities. Some high pressures have been observed in the Corsicana Oil Field, Navarro county, and to the south of San Antonio, Bexar county. Beyond the local consumption under boilers for running drill rigs, natural gas is hardly used at all in Texas. Enormous pressures were observed at Spindle Top, in the Beaumont Oil Field, and recent wells at

Sour Lake, Batson's Prairie, in Matagorda county and elsewhere have shown a great quantity of natural gas under extremely heavy pressure. The composition of the gas at Spindle Top, Sour Lake and Batson's Prairie has not been determined by this survey. At many wells it had an evil odor and was destructive of human life in more than one instance. We made some calculations of the pressure at Spindle Top when there were 70 oil gushers in operation and the result was to show that irrespective of the pressure required to throw the oil into the air to heights varying from 50 to 80 feet, the pressure required to bring the oil to the surface in these 70 wells was about 2,200 pounds per square inch. In some cases the pressure was doubtless much greater than this. In one well in the Beaumont Field there was such pressure that more than four hundred feet of 4-inch casing was blown clear out of the hole, having been torn loose at the threads and forced up against the friction of the earth strata. The first well at Spindle Top, the "Lucas," developed such a pressure that six tons of six-inch casing were blown clear of the hole and lay in a tangled mass at the foot of the derrick. The so-called "mud wells" which throw out vast quantities of mud for hours together owe their origin to pockets of gas under high pressure.

We have examined but one sample of natural gas and that from the Navarro county fields. Its composition was as follows:

Composition of natural gas from Navarro county, Texas:

Carbon Monoxide	3.70	per cent.
Marsh Gas	64.00	"
Hydrogen	1.70	"
Heavy Hydrocarbons	4.20	"
Oxygen	0.90	"
Nitrogen	25.50	"
Sulphur	None.	
B. T. U.	784.40	"

This is a good gas and would probably make a fair illuminant, in connection with a Welsbach or similar burner, and it has a good heat value.

It would appear that the exploitation of the gas fields a few miles south of San Antonio might be undertaken profitably. This is the largest city in the State and the gas fields are within fifteen miles of it, showing good pressures. None of the known gas fields in Texas have been drawn upon sufficiently to enable one to speak of the continuity of the supply. This is an important consideration, as some other places have found to their cost. For burning brick and cement, natural gas is an ideal fuel and it is strange that none of the large establishments of this kind situated within easy distances of known gas fields have used it. It is to be expected that with the growth of industrial enterprises in the State there will come a larger use of natural gas. As a domestic fuel in a mild climate it has very great advantages. But the gas fields of Texas remain for the future. Reference is made to them here merely to point out their existence in connection with other hydrocarbons.

DISCUSSION.

Mr. W. L. Abbott—I would like to ask Dr. Phillips if there is any connection between the oil fields and the coal fields?

Dr. Phillips—None at all; they are entirely independent. That is as I understand it. I believe there is a popular fallacy, supposing that oil comes from coal, on account of its being called coal oil.

Mr. A. C. Schrader—I would like to ask why rock asphalt was not shipped for any great distance?

Dr. Phillips—The freight rate now is $3.00 per ton from the mines to San Antonio, and the asphalt will not stand much further haul at that rate. Shreveport is reached, by some concession on the part of the railroad companies, but shipments have never been made further east than Shreveport.

Mr. W. H. Finley—Yet asphalt is shipped here from Europe.

Dr. Phillips—That is accomplished on account of water rates being so much cheaper than railroad rates.

Mr. Finley—How does the Texas rock asphalt or limestone compare with the foreign asphalt—say Seyssel rock?

Dr. Phillips—It is almost identical and has the same composition. Where well laid, as in some of the streets in San Antonio, it is wearing very well.

Mr. Finley—What do they use to flux it with?

Dr. Phillips—Nothing whatever.

Mr. Finley—As I understand it, nearly all the foreign asphalt used in this country is fluxed.

Dr. Phillips—Yes, I believe that is true. You have laid some in Chicago, have you not?

Mr. Finley—Yes.

Dr. Phillips—In our observations of those rock asphalts—whether sandstone or limestone—we have found that leaks from gas mains prove destructive to the pavements where they are used. There are many disintegrations of the asphalt pavement due to leaks of illuminating gas. In a short time the rock becomes extremely brittle and you can dig it out with a lead pencil. Of course attention has already been called to this fact, but the matter has not received the attention that it should have.

Mr. Finley—In your paper you mention a material called "bone." What is that material?

Dr. Phillips—It is really a carbonaceous slate that may carry 15 to 20 per cent volatile matter. It is really nothing but a slaty coal; it is not used for anything and is not worth anything.

Mr. Abbott—Do you wash your coal?

Dr. Phillips—No, there are no washers in Texas.

Mr. Abbott—I do not see how they can produce a marketable article without washing it.

Dr. Phillips—Indian Territory coal costs from $6.00 to $8.00 per ton. If we can get the other for $3.00 we use it.

Mr. E. C. DeWolf—I would like to ask by what means the coal and lignite are mined. The prices given are so much lower than the ordinary prices, that it leads me to wonder how they get it out; also whether they take it all out?

Dr. Phillips—I think most of the lignite mined is by what might be called a "Texas System." They will cut a tunnel right through the lignite and arch it up for the roof. It is all done by a modified system of long-wall, but I do not think anybody who ever saw a long-wall in Illinois would recognize it. They pay 25c a ton for digging that lignite in seams 4 to 6 feet thick and upwards; 20c for seams 8 to 12 feet in thickness, the roof being the lignite itself and supported now and then by props at irregular intervals. There is no reason why the roof does not fall in, and as a matter of fact it does; still, there are very few accidents. It is a rare thing to see any report of an accident in a coal mine. In other coal mines, where the seams are narrower, they have to be much more careful.

Mr. Warder—Is that lignite soft enough to work in it with a pick and shovel?

Dr. Phillips—Yes, there is not much blasting done.

Mr. E. N. Layfield—I would like to ask Dr. Phillips if, in speaking of "the last of the oil gushers," we are to understand that the oil is becoming exhausted?

Dr. Phillips—Simply that the pressure is dull, because of the enormous demands made on it; they are still getting out a very large amount of oil; just how much I cannot tell, because we have been unable to get the exact statistics. It is a matter of importance to know what the production of oil was last year. Mr. Oliphant, who collects the oil statistics for the United States Government, does not yet know what the oil production was for last year.

Mr. Abbott—Is this oil refined and used for lubricating?

Dr. Phillips—Yes, there are two refineries down there.

Mr. H. G. Dimick—What are the smoking qualities of the lignite as compared with soft coal?

Dr. Phillips—It smokes quite badly; the shade is more brown than black. We have some large problems to handle down there, as the population is increasing very rapidly, there being now nearly 4,000,000 people, but there is no fuel to build up great enterprises on. Many of these problems will be solved by the use of lignite.

Mr. Abbott—Did I understand you to say that the price of this oil is about 60c a barrel?

Dr. Phillips—Yes, nominally.

Mr. Finley—Are they producing any asphalt from the Beaumont fields?

Dr. Phillips—Only as residuum from the refineries.

Mr. C. O. Billow—Are they making any briquets from the Beaumont oil?

Dr. Phillips—No.

Mr. F. A. Flather—What commercial use do you make of the asphalt oils?

Dr. Phillips—They are distilled in the refineries at Port Arthur and Houston.

Mr. Flather—Is any of it used in crude form for fuel purposes?

Dr. Phillips—There are some engines on rice farms using crude oil, and an engine of 28 brake H. P. will deliver about 20 H. P.

Mr. Billow—They do not have any difficulty in burning the oil under boilers do they?

Dr. Phillips—No; no trouble under locomotives.

Mr. Flather—Can they burn it without smoking,—can they prevent the burner from smoking?

Dr. Phillips—Yes, large water boilers run days at a time with but a slight gray haze at the top of the stack.

Mr. Flather—Do not the pipes and burners clog up at all?

Dr. Phillips—To some extent at times. The best installations are with steam, instead of compressed air.

Mr. Abbott—With oil at 60c a barrel and coal at $6.00 a ton I do not know why they burn any coal in Texas.

Dr. Phillips—The great consumption of coal is for domestic purposes; there are few large manufacturing establishments.

Mr. Finley—How does the Beaumont oil with the asphalt base compare with the units of the oil with the paraffine base?

Dr. Phillips—There is not much difference. In practice they will tell you anywhere that from 3¼ to 3½ barrels of oil is equivalent to a ton of good soft coal—Indian Territory coal.

Mr. Billow—That Indian Territory coal is a pretty good quality of coal, is it not?

Dr. Phillips—Yes.

Mr. Flather—How do you extinguish those large oil fires?

Dr. Phillips—They generally have to burn out, practically. They isolate them. Where they can catch them in time they extinguish them with steam.

THE DEVELOPMENT OF REINFORCED CONCRETE IN EUROPE.

By E. Probst, C. E., of Vienna, Austria.

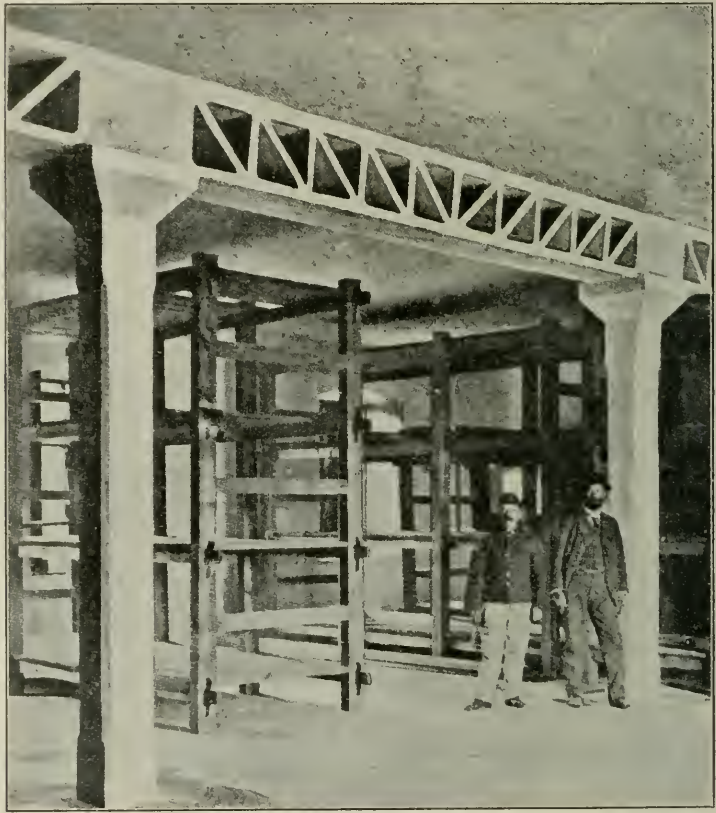
Read Nov. 2, 1904.

A concrete construction firm exhibiting at the World's Fair advertises: "We do what they did 2,000 years ago." It is true they did it, but how, and in what connection? Twenty years ago concrete work was built, but what a big difference there is between that time and now. No other branch of engineering work has progressed as much as concrete (and especially reinforced concrete) construction in the last few years. It is too early yet to call our age the "cement age," but there is no doubt that the coming age will be the "concrete age."

You gentlemen have more opportunity for big works than European engineers. You have the largest bridges. My countryman, Prof. Melan, did not see as many bridges of his design in Europe as you have built in one year. But in one point Europe and America are alike. It is the introduction of a great many systems which are of little advantage. For instance, the man who has done more in Europe than any other man in introducing reinforced concrete in building construction, is Mr. Hennebique, whose system is not modern at all. He has created both in Europe and America a system business, but a man who did not want to pay for using Hennebique patents simply changed a stirrup or some other detail and got a new system, usually giving it a new title.

Unfortunately many of these people did not understand the concrete business, and they have retarded the development of concrete construction. But now the public is getting more and more familiar with this construction and does not object to using concrete as a building material. For this reason I think engineers ought to be cautious and do all they can in studying this modern building material. The more tests and the more calculations we make which give satisfactory results in practice, and the more scientifically we try to treat this subject, the more we approach "the concrete age."

Reinforced concrete was used in the United States and England a long time before the magnificent qualities of this material were fully known. I think it is for nearly fifty years. In Europe no reinforced concrete was known or used at that time. In recent years the gardener, Monier of Paris, accidentally found out the good qualities of concrete, and afterward of concrete reinforced by wire netting, which he used to make his garden pots or flower pots less fragile. After having seen his success, he made reservoirs and pipes of reinforced concrete, but no scientific treatment was known to him. The era of reinforced concrete commenced when civil engineers, both theoretically and practically educated, became interested in this line and started to build all kinds of construction and to find out the best way to figure them. At nearly the same time, reinforced concrete was used in buildings by a Belgian architect. He was asked to build a fireproof residence. He chose steel and stone. An experience in a fire in a factory showed him the necessity of enveloping the iron to protect it from the direct influence of the fire, and he used for this purpose cement mortar. In this case the mortar had only to protect the iron, and the iron-structure had to carry the whole load. Later he reduced



Girder of Visintini Design Supporting a Floor.

the section of the iron and used both the concrete envelope and the iron to give the required strength.

The fatherland of reinforced concrete is undoubtedly France. I mention the fundamental results which Considere got out by his tests, which showed the superior qualities of the combination of concrete with iron. He found out how superior are the qualties of concrete reinforced with iron above the concrete alone. He discovered what created so much sensation, that reinforced concrete can extend 10 to 20 times as much as concrete of the same composition without any iron, and it was explained that the iron had the quality to make the concrete more extensible, a quality which we cannot explain.

Results obtained from 31 large beams of six different kinds of reinforcement show practically the same results as those of Mr. Considere, that the concrete reinforced with iron has a larger extension than concrete alone.

The two principal questions always mentioned by the enemies of the new construction material, are:

1. Does the iron embedded in concrete rust, and what influence has this rust on the construction?

2. Is there any adhesion between iron and concrete; and if so, how strong is it?

Practical experience has shown that the iron embedded in concrete does not rust. Baurat Pfeuffer, vice-president of the Austrian Society of Civil Engineers, and a prominent bridge engineer, had to rebuild a bridge with piers o fstone embedded in mortar. When he pulled down the piers he found, in this old construction, a hammer embedded in the mortar, which one of the laborers had probably lost during its construction. It was very hard to tear off the mortar and the tool was perfectly polished, and without any rust on it. This shows the adhesion between concrete and steel, and also shows that iron does not rust at all in concrete.

Bauschinger made tests in 1892 for the purpose of ascertaining if too much water used in the concrete does not hurt the iron; and he used broken test pieces of reinforced concrete, laying them in water, in the air, and in ditch water for some time, and he found that the reinforcement was not damaged at all by the influence either of water or changes of temperature.

In 1892 Wayss and Freytag, well known contractors in Austria and Germany, built in a small city the whole water pipe system of reinforced concrete. These pipes were some time under water and were of very small dimensions, and the reinforcement was only wires of a very small section. A few months ago the firm asked the city building department to change one pipe at the risk of the firm. The results certified by the city building department, were published in our periodical paper, "Concrete and Steel," and show that the small wires had not rusted in the least, and the adhesion results were satisfactory; and these tests were made of the pipe after eleven years' service. Theory has shown that cement is the best protection against rust, consequently we have to use for reinforced construction a pretty fat mixture of cement mortar.

Mr. Moersch from Berlin, now professor in Zurich, has made tests of the adhesion between concrete and steel, and finds that with certain mixtures the adhesion was as follows

Cement & Sand	Water	Adhesion.
1 to 1	10%	46 kg. per. sq. cent.
1 to 2	15%	49 kg. per. sq. cent.
1 to 3	——	40 kg. per. sq. cent.
1 to 4	——	38 kg. per. sq. cent.

He found after a number of tests of reinforcement by plain bars that to reach the best adhesion between concrete and steel, it is necessary to take a sufficient percentage of water; i. e., to make the mixture plastic. He shows further that the adhesion is small with a poor or lean mixture of cement mortar, and that the adhesion is higher with a fat mixture.

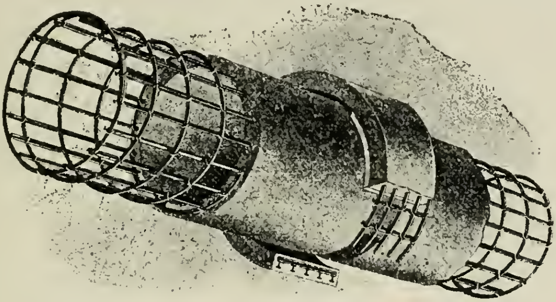
Some engineers, especially here in the United States, claim that the adhesion ceases after a number of years, and that afterwards there is only the mechanical bond between iron and concrete. We have used in Europe until now, as far as I know, only plain bars, and we have built reinforced concrete for a long time, and the results do not show any failure on account of incomplete adhesion between the concrete and steel. Of course we have to be very cautious in this matter, and to wait for more tests and studies in this line before we can arrive at definite conclusions.

There is no doubt that reinforced concrete is fire-proof. You have seen the results of the Baltimore fire and some others, and in my mind there is no building material as fireproof as concrete.

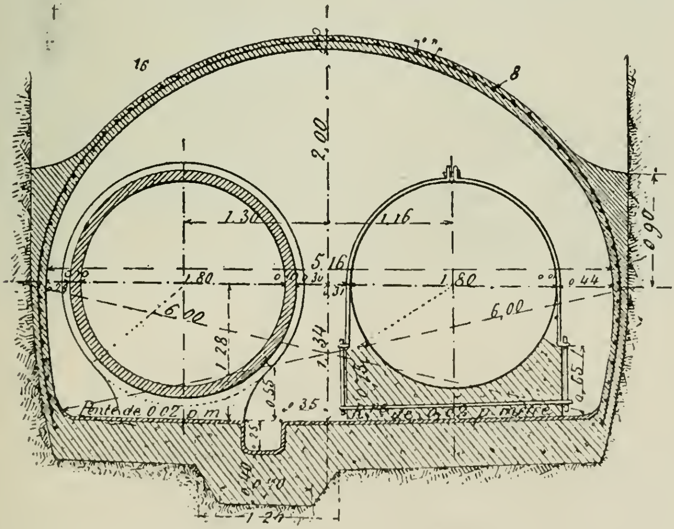
In this short paper, which may give you only a small idea of the development of reinforced concrete construction, it is impossible to speak of all kinds of construction which can be done in reinforced concrete.

I mention the different bridge systems with and without hinges. Hennebique bridges have not shown very good results, as Mr. Considere states in his paper before the Engineering Congress. The Monier system of reinforcing concrete arches with wire netting has led to the development of a great many arch systems, more or less successful. Prof. Melan's system has been much used by the Concrete Steel Engineering Co. of New York, and was introduced in this country by Dr. von Emperger.

In the matter of water pipes, I would mention the Bordenave system. The reinforcement is of "I" beams in both ways, thus providing a good connection between the iron and the concrete. This has been used for the construction of a pipe system in L'once-el-Vebir in Algier. Bordenave made his first exhibit in Paris in 1889. Coignet and Bonna have used their own system for water pipes, and construction made in the Coignet system.



Reinforced Concrete Pipe for Conveying Water.



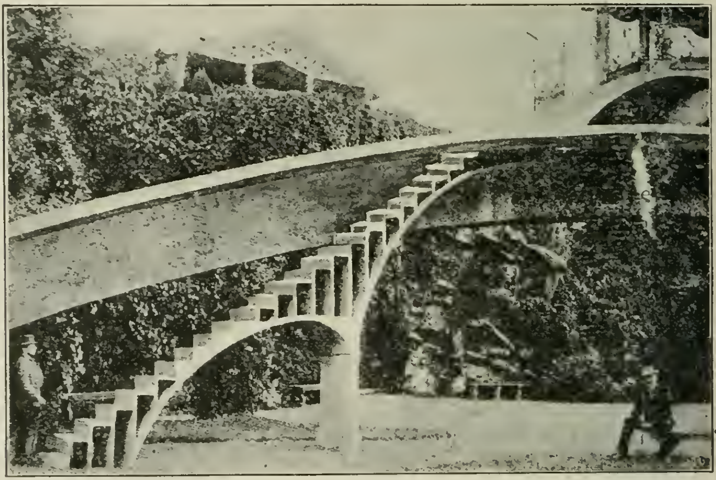
Reinforced Concrete Pipes Placed in Subway of Reinforced Concrete.

In Paris, where they used a great deal of reinforced concrete pipes, they have found that it is about 20 per cent cheaper than masonry work.

But all above mentioned works are only to show what has been done in Europe in this line since 1889.

I would like to go more thoroughly into the use of reinforced concrete as building material, which is most interesting at the present time. In building construction the use of concrete for foundations are footings is generally acknowledged to be the best on account of its high compression strength and its cheapness. In columns made of concrete, reinforcement is necessary not only to provide against lateral bending and shear, but also to prevent cracks. Besides the Hennebique system, a great many other systems are used. In Hamburg there is a six-story factory building of reinforced concrete, with the front columns covered by sandstone.

Stairways have been built in reinforced concrete for several years, and a stairway was built ten years ago in the garden of the Portland cement factory in Stettin, Germany, on the Monier system. The stairway is supported by two arches, and was loaded after the erection with a load of 100 lbs. per square foot and did not show any crack.



Reinforced Concrete Stairway, Monier Construction.

A very difficult construction in reinforced concrete is a cupola, which was made in 1889 to cover the tomb of Emperor Frederick in Potsdam. The construction is on the Monier system. The ten ribs are reinforced by wire netting and both on the outside and inside is a small sized Monier covering. The roof was covered with copper, and the space five feet above the base of the cupola was filled with concrete, to take up the push from the ribs. The lantern which crowned the cupola was also made on the Monier system.

A new building erected in Vienna (Austria) has a corner tower or cupola of reinforced concrete construction. The radius of the cupola is about 9 feet 6 inches. Its height is about 15 feet. It is made on the Monier system reinforced by wire netting.

By far the most interesting and difficult design is that of the floors in a building. I remember the most simple constructions in the beginning of the concrete era, concrete arches between I beams which were used a great deal in Europe in factories and other common buildings.

The Koencu Vountenphatte, so called after the well known pioneer of concrete works in Berlin, has a reinforcement embedded in the concrete, attached to T beams on both sides, this reinforcement being made according to the difference in tensile strength in different sections.

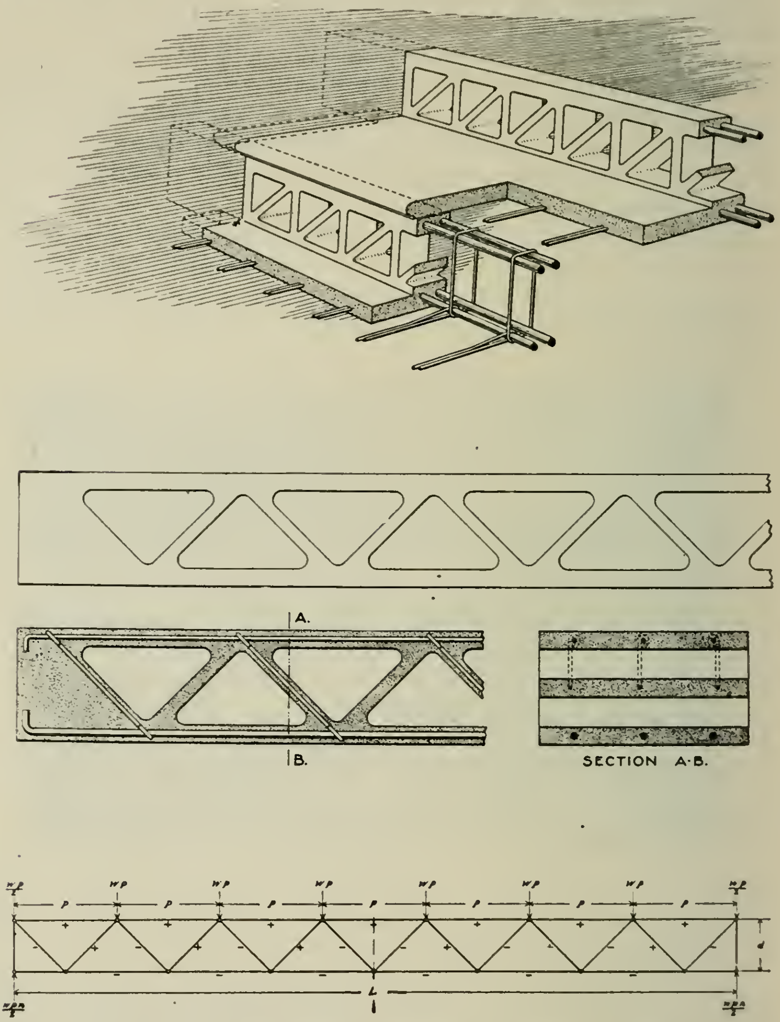
Many other systems have been made, like or unlike Hennebique, with stirrups or without stirrups, for protection against shear. All of these have the disadvantage that they obstruct the building, and that it is necessary to make them in place with more or less centering and that they are solid, which are very heavy, and that need very much material. Mr. Siegwart, a civil engineer in Switzerland, invented, three years ago, a really new system. He designed beams like wooden or iron beams in a factory, making them hollow, thus reducing the weight, besides other advantages. Visintini, an Austrian, who has worked in concrete and reinforced concrete in Switzerland, invented a new system two years ago, a real latticed system of beams in reinforced concrete.

The Visintini system of girders can be used for floor construction as well as for bridge construction. The principle of the construction is that every beam can be made either 8 inches wide or 1 foot wide.

In the first case two iron frameworks for reinforcement are embedded in the concrete in two longitudinal sections 5 inches apart, one rod in the upper flange and one rod in the lower flange, both rods connected with iron ties.

In the second case—1 foot beam—there are three reinforce frameworks embedded in about the same distance as in the 8 inch wide beam, the rods in the tension member being simply bent around to the upper and lower flange. They are put in place side by side under recesses; the space between the two beams is filled out with mortar in a mixture of 1 to 3.

From a theoretical point of view it has the same advantage over the solid beams as latticed steel girders have over the plain plate girders. The stresses are distributed in the center of every member as we assume hinges at every panel point as in lattice steel girders. The concrete is only to take up compression and it is not



Reinforced Concrete, Visintini System for Stairways and Beams.

figured for tension, the tension being carried by the steel bars, which are embedded both in the upper and lower flange and in the ties; the diagonal struts are made in concrete only, as there is no tension in them, and the concrete alone can take up the compression stresses. It would not be necessary to reinforce the upper flange, because it has no tension in it except to furnish attachment for the diagonal ties.

The design of these beams is very simple; the stresses of every member can be figured both in an analytical and graphical way in the same manner as for lattice steel girders. After having figured the stresses, it is easy to find out the section of every member; the tedious method necessary to figure the neutral axis in other systems is not necessary in calculating the Visintini lattice girders, as the resultant stress works to the center of every section. The girders can be made to a span of about 30 feet.

Mr. Visintini designed a bridge for Breslau (Germany) with a clear span of 35 feet. The beams were 8 in. wide, with the upper flange 6 in. thick at the center, and 4 in. thick at the support, and with 4 bars, of ⅜-in. diameter.

The lower flange was uniform, 3.5 in. thick; with 4 bars of 1-in. diameter, and the diagonals were 1½ in. thick; with 4 bars ½ in. diameter. The height of the beam is about 28 in. at the center; the live load was 160 pounds per square foot, and the dead weight about 80 pounds per running foot.

Both Siegwart and Visintini beams are fireproof. The Siegwart beams, which were tested in New York city last August, withstood a fire of 1,800 degrees F. all right. The Visintini beams stood fire tests at the London Exposition fire in 1903, and a new test, which was made about two months ago in Trieste, showed the best results for the protection of the iron against the fire, although the concrete protecting the steel bars is only ⅜-in. thick.

The test was carried out on two girders, each 10 inches high, 8 inches wide, and a length of about 17 feet; between the two beams was supported one Monier slab, 1½ inches thick and about 4 feet wide. These two supports, attached to the beams, were 1½ inches high and 1¼ inches wide. The clear span of the girders was about 16 feet. The floor had a dead load of 32 pounds per square foot, and was loaded with 2,000 pounds. The fire, which was made to test this floor, lasted half an hour, and was of a temperature of about 2,000 degrees Fahrenheit. It was extinguished by water, then the floor was allowed to cool off and was loaded with 2,620 pounds, which is nearly five times the safe load. The girder showed not the slightest cracks—only a deflection of about ¾ inch, and broke down under a load of 2,800 pounds. The beams had an age of only a few days.

The advantages of this system are as follows:

1st. The beams can be made in a factory under good supervision, and prepared during the excavation and other building work.

2nd. They have a minimum of material and more strength than a solid beam of the same height.

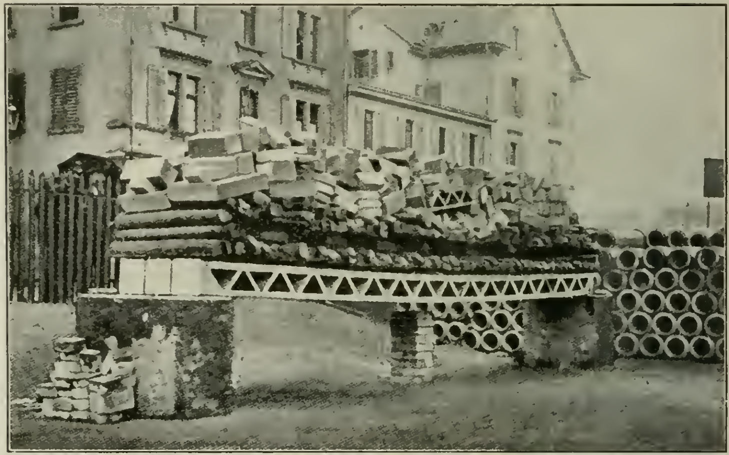
3rd. Their dead load is less than by other systems.

4th. The flues can be used for pipes and conduits.

5th. The flues are filled with air and temper the building and make it impervious to sound; the vibration is less than with solid construction, as these are distributed at every panel point.

In closing I would like to mention the pioneers in the concrete steel science in Europe; most of them you know very well.

In France, Mr. Considere, whose testing works are known all over the world; Mr. Christophe, whose book, "Practical Treatise on Reinforced Concrete," was the first collection of executed works in reinforced concrete; Mr. Coignet; and the father of reinforced concrete business, Mr. Hennebique; and last, but not least, Mr. de Tevesco, whose book, printed a few months ao and containing designs of reinforced concrete work of different systems, will be more appreciated a few years later, as it is the work of a man who has worked in plain and reinforced concrete since the beginning. In Germany: The theorists are Bach and Bauschinger, Koenen and Prof. Moeller, from Baunschweig. In Austria: Dr. V. Emperger, the editor of our periodical paper, "Beton und Eisen," a man who is known in the United States as well as in Europe.

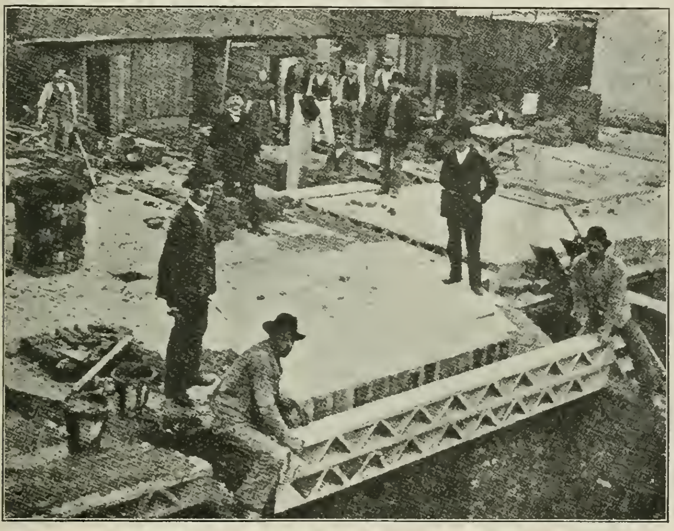


Reinforced Concrete Beam, Visintini System, Under Test.

Gentlemen, what I have told you about the development of reinforced concrete in Europe and of the new types of construction is only a very little view of what is done and what is being done in Europe, and I only wish we Europeans could have more understanding with you than only by the papers. Engineering works are international, and a scientific understanding by the civilized nations helps very much; and so I hope we will have more exchange of ideas in the future in the particular line of reinforced concrete construction.

DISCUSSION.

Mr. W. L. Abbott—It is difficult now to comprehend how reluctant people were, only a few years ago, to use concrete. I can remember that fifteen years ago scarcely any reputable engine builder would risk his engine on a concrete foundation. They would say, "Concrete *may be* all right, but we know that a foundation built of brick or stone is all right." With the development of concrete work, and especially reinforced concrete work, within the past ten years, we may look for more startling improvements in the future.



Reinforced Concrete Beams, Visintini System, Being Set in Place for Floor Construction.

Mr. McCullough—I think there was a little misstatement in a remark that Mr. Probst made about the reinforcing of the experimental beam; that is, I believe he stated that the reinforcement in the upper cord of the beam was three inches. This should have been three rods, each of one inch, should it not?

Mr. Probst—Yes, you are correct.

Mr. Schaub—I have been very much interested in this paper, in as much as it confirms, in a measure, some of the practice in this country; but I must confess that I was a little disappointed that there were not some structures shown which are used for carrying vibrating loads, such as railway bridges. The use of concrete for static loads is entirely different from its use for vibrating loads, and I would like to ask whether such structures are used for railway purposes?

Mr. Probst—Not very much. As far as I remember, arch bridges for railways have been made 50 to 100 foot span; I know of some works of Wayss and Freitag in Bavaria, also two in Austria; but I do not remember very much other work in railway bridges.

Mr. Schaub—I do not think any of the American railway engineers would risk a structure built on the lines illustrated tonight. I think, too, that the forms of construction are running a little wild, both in this country and in Europe. I feel sure than an American engineer would not approve of the lattice form of girder, such as was shown on the screen, for railway purposes in this country.

Mr. Probst—As far as I know Mr. Visintini did not expect this system would be used for large railway bridges.

Mr. Schaub—If the principle is right in one case, it seems to me it ought to be right in all cases.

Mr. Probst—The principle is all right for buildings and highway bridge purposes, but it has not been figured out for moving loads, such as in large railway bridges.

Mr. Finley—But why have they not gone more into railway bridge work in Europe?

Mr. Probst—First, because they do not do very much work in railway bridges in Europe in the line of reinforced concrete. The same is true there as here in the United States—that reinforced concrete is not very much liked by engineers who are not interested in reinforced concrete works or by the railway people.

Mr. Findley—Have you had any trouble from the failure of reinforced concrete used for buildings that would lead others to doubt the advisability of its use for railroad bridges?

Mr. Probst—We had the first failure in Switzerland some years ago in the way of building construction; the construction, I believe. being very much like the Hennebique system. From that time the development of reinforced concrete was interrupted for a long time in Switzerland, but concrete and reinforced concrete is once more being used very extensively. Especially in Vienna and Berlin they are using it for floors and columns.

Mr. Finley—Have they had many concrete failures?

Mr. Probst—Not many; the failure I referred to at Munich was not due to the concrete work, but was the fault of bad supervision.

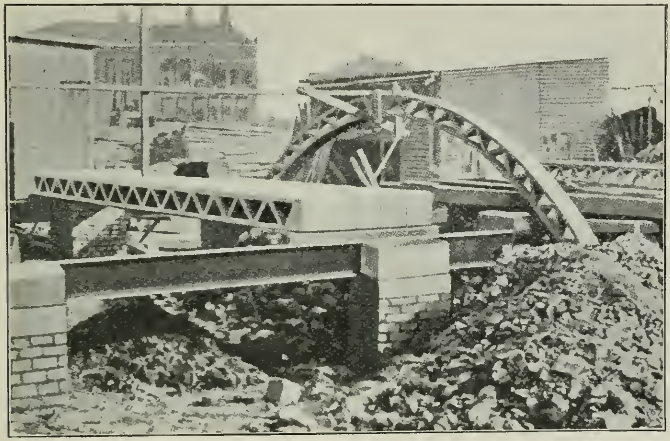
Mr. Finley—What I am trying to get at is the nature of the failures; whether they were due to the form of construction, materials or poor workmanship?

Mr. Probst—I am inclined to think that both the bad centering and poor labor caused these failures.

Mr. Finley—What would you think would be the result in the case of a building constructed according to the last form shown in the illustration, in the case of a slight earthquake. What would be the effect on that type of construction?

Mr. Probst—The effect would be the same as in any kind of construction. Did you think the effect would be different in this particular kind of construction?

Mr. Finley—I question whether a building constructed according to that form, if subjected to an earthquake, would prove as efficient as steel construction, for the reason that the concrete would be subject to stresses.



Reinforced Concrete Beams, Visintini System, may be Arched as Well as Flat.

Mr. Probst—I believe in reinforced concrete, and I think an earthquake would have no more effect on a reinforced concrete construction than with iron or steel construction.

Mr. Finley—From the fact that you are not developing reinforced concrete in Europe—the home of it—this indicates that you have not confidence in it yourself.

Mr. Probst—If I could build a bridge now in Europe, I would do it right away. Mr. Lindenthal, who is a steel man, told me a few weeks ago at the Engineering Congress that he is now giving a good deal of study to reinforced concrete bridges for railway purposes.

Mr. Finley—Yes, a great many are dreaming about this.

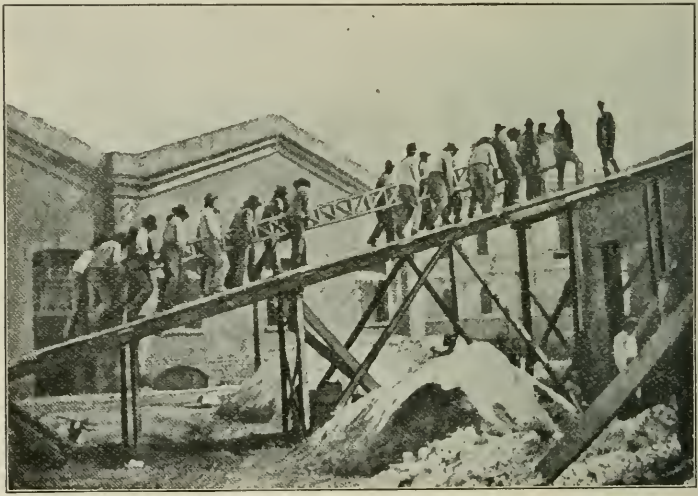
Mr. Seafert—Is there not a design of a bridge in the railway exhibit in the Austrian Building at St. Louis?

Mr. Probst—In the Austrian Building there is a model of the false-work for a 240-foot span bridge now being built entirely of concrete; a single arch, and not reinforced.

Mr. Schaub—Perhaps I may have given Mr. Probst the wrong impression. There are some railroad bridges being built, but not according to the design shown on the screen.

Mr. Spelman—Would the bars, in the compression flange, take care of the earthquakes?

Mr. Probst—I will simply say that we will have to wait for the next earthquake.



Reinforced Concrete Beam, Visintini System, made away from the Building but to be carried there and set in place.

Mr. Abbott—The object, as I understand it, in putting those iron bars in the upper flange is for mechanical strength in handling it.

Mr. Probst—It is only for better connection between the lower and upper flange. Otherwise it would not be necessary to put any iron in the upper flange.

Mr. McCullough—As I understand it, you place in the tension members of that truss, tension rods to take up the stress.

Mr. Probst—The tensile stress is only taken up by the rods and the concrete does not take up any tension stresses.

Mr. McCullough—In the tension members of the trusses or beams you put wire, or rods, and it is connected, by the stirrup, to the longitudinal bar in the beam and the top members. The idea that these gentlemen were trying to convey was that putting longitudinal reinforcements in the upper member of the girder causes an actual loss of strength. Could not that matter of connecting the rods be arranged by putting in the top member pieces going across, instead of lengthwise of the girder?

Mr. Probst—I do not think it is necessary. As far as I know the longitudinal rods all make the upper flange stronger, because the iron, in connection with the concrete, has to take up the compression in the upper members.

Mr. McCullough—But in the experiments that have been made, any reinforcement made in the compressive side of the bar tends to lessen the strength of the bar. What factor of safety do you use?

Mr. Probst—The factor of safety is 10 for concrete and 5 for steel.

Mr. McCullough—It might be interesting to make one without any longitudinal rods in the top member, one with longitudinal rods, and then make another with the pieces across, and test all of them, similarly.

Mr. Probst—The results of tests which have been made with the longitudinal rods have been very satisfactory.

Mr. McCullough—The idea that these gentlemen are trying to bring out is that in the case of stresses in the steel concrete construction, the presence of that longitudinal reinforcement in the top member of the Visintini beam, might prove a source of weakness.

Mr. Probst—But I do not think that is the case.

Mr. Condron—In regard to the factor of safety, Mr. Probst says that in their designing they use a factor of safety of 10 for concrete and 5 for steel; what is the element of stress in the steel taken at? Or, what is your working stress in the steel?

Mr. Probst—Fifteen thousand pounds per square inch.

Mr. Abbott—Am I to understand from that a reinforced beam would be stronger without concrete in the lower member, or with the steel not encased in cement?

Mr. Condron—No, that is not the correct understanding.

Mr. Abbott—I understood from your statement that the beam fails when the steel reaches its elastic limit.

Mr. Condron—Yes, it does.

Mr. Abbott—If it were not encased in cement it would not fail until it reached its limit of strength.

Mr. Spelman—Am I correct in understanding that the statement was made that a beam with reinforcing rods on the upper side are not as strong as one without them.

Mr. Abbott—That was the statement made.

Mr. Spelman—That putting steel in the compression side of the beam would weaken it?

Mr. McCullough—The experiments that were made showed that a solid beam, reinforced both in the top and in the bottom, did not develop the same strength as in a beam reinforced in the bottom alone.

Mr. McCullough (by letter)—It seems hardly a proper thing to look too soon for a general application of this system to the construction of highway and railway bridges. The idea of the inventor seems to have been to secure economy of material and lessening of dead load in building construction. Advocates of concrete fire resisting construction as opposed to tile fire proofing have here a system which removes at once the principal objections to concrete,—excessive weight. It also settles another great objection, namely, slow construction because of the necessity for the use of forms, which cannot be removed until the concrete has sufficiently set.

The Visintini beams and columns can be built in factories and brought to the building site precisely as metal is now brought. They are set in place without forms or special devices of any kind, and at least as readily as wood. The form of truss is simple, and the calculations simple. The concrete is not expected to carry any tensile strain, and the tensile members are of steel protected by an envelope of concrete. The compressionmembers are entirely of concrete. The presence of metal in the upper chord makes no exception, as it is simply placed there to tie the diagonals to the lower chord. A transverse piece at the panel points would serve as well, but would not be so convenient. The system has nothing to do with the question of the employment of plain, corrugated, or bulbous rods, but is simply a new method for reinforced concrete construction, designed to save material and weight.

It is common nowadays to hear engineers say that steel concrete is only better than solid concrete construction when the reinforcement effects a saving of fifty per cent of concrete. If this is only partly true, such a system as here described will repay investigation.

SOME INTERESTING PHASES OF LONG-DISTANCE TELEPHONY.

S G. McMeen, M. W. S. E.

Presented before the Electrical Section, Nov. 11, 1904.

Long distance telephony as a practical commercial art, is of relatively recent origin in comparison with the actual use of the telephone in business and social affairs. Telephone exchanges existed twenty-five years ago, but until the adoption of two similar wires for each circuit and the adequate treatment of circuits with relation to each other to prevent mutual interference, conversations at all to be called "long distance" were limited to radii of twenty-five miles or so. By the use of two-wire lines, instead of one-wire-and-ground-return lines, successful talking over radii of a thousand miles or more has been possible and has been practiced for about twelve years.

The original telegraph lines laid and erected by Professor Morse were of two similar wires per line, and the early circuits copying after his, both in this country and abroad, were so arranged. Once upon a time, one wire of such a line in Germany, in breaking, fell with both its ends upon the earth and in reasonably good contact with it. The circuit continued to be a practical telegraph line even with this interruption of one of its sides, and the observation of Steinheil enabled advantage to be taken of the accident to the result of grounding these two wires immediately at the end stations. This resulted in the universal adoption of one wire and a ground return for all telegraph purposes, and it was only natural that such circuits, having become universal for telegraphy, should be adopted for telephony when the latter made its appearance immediately after 1876.

But grounded circuits for telephone purposes suffered greatly from mutual induction, styled "cross talk," and had the further disadvantage, if of a few miles length, of suffering from strange and disturbing noises from electrical changes from instant to instant in the atmosphere and in the earth. These sounds had some interest from a physical point of view, as they were so unlike sounds ordinarily met in life that they seemed to point to a possibility of a useful study of weather and other conditions of the earth. Practically, however, they were a great obstacle to successful telephony, and their abolition by the use of the two-wire line, or metallic circuit, made a distinct new progress possible.

The early wires were all of iron or steel, copper being unsuitable because of its tendency to stretch and then to break. When it was made possible to draw wires of copper in such a way as to provide a strong, hard outer surface, bare line wires of sufficient strength and economical smallness were available, and two such wires formed, and still form, the highest type of long-distance telephone circuit.

SIMULTANEOUS TELEPHONY AND TELEGRAPHY.

The cost of the path over which talking may be done between points widely separated is so great, for a variety of reasons, as to prevent a wholesale use of so valuable an aid. A principal reason why the investment cost reacts upon the consumer of the service is that the circuit is available for personal conversations during only such hours as the people furnish the work to be done, and a considerable reward always has awaited an arrangement which would utilize the idle time of these expensive circuits in any way allowing by-product values to be secured. The only way which has been

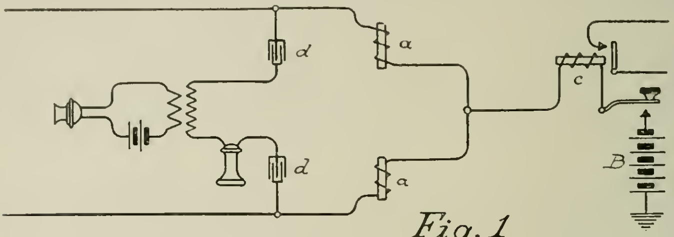


Fig. 1

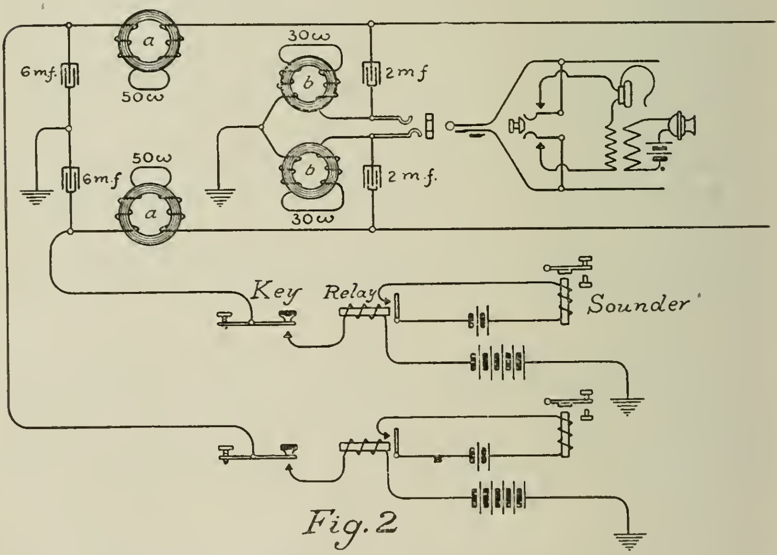


Fig. 2

found so far is that of utilizing the wires of the telephone circuit for the purpose of telegraphy, as well as for transmitting actual speech, and this has been accomplished by taking advantage of the very considerable difference in the frequency of telegraphing currents and actual voice currents.

Van Rysselberghe, of Belgium, has made the largest contribution to this art. It is a development of his system which utilizes each wire of a circuit for telegraphic purposes, whether it be or be not used for talking at the same time as well. A simple form of simultaneous working, quite rightly named "Simplex," is that illustrated in figure 1, and provides one telegraph circuit from each metallic circuit telephone-line. Broadly speaking, this circuit is not dependent upon a considerable difference in the frequencies of the telegraphic and speaking currents, but only upon the fact that the telegraphic current passes over both sides of the line in the same direction at the same time, while the speaking currents circulate in the metallic circuit as such. Simultaneous potentials on the two sides of the line naturally prevent any sounds from the telegraph appearing in the telephone circuit. The coils *a* and *b* are inductive ones, and through them equal currents pass to the two telephone wires in parallel, each current being half of that from the battery B through the relay *c*. An arrangement quite similar, at the distant end of the line, receives the telegraphic signals. Variations from this type exist in the use of repeating coils instead of impedance coils, and a variety of arrangements can be suggested by any one familiar with both the telegraphic and telephonic arts. In any such arrangements the condensers *d* are not essential, but have certain minor values.

The contribution of Van Rysselberghe has led to the possibility of utilizing a metallic circuit not only for telephony, but for *two* independent telegraph circuits as well. Figure 2 illustrates one of the forms widely used for such purposes. It being understood that the distant stations are quite duplicates of those shown in figure 2, a little thought will make plain how the two things can go on at the same time without interference. This will be easier when it is remembered that the condensers shown are relatively transparent to alternating currents and opaque to direct currents. Also that the choke coils *a*, while they have each two windings upon the ring core, have those windings connected in the familiar differential or reversed relation to each other. So far therefore as direct currents are concerned, the magnetizing effort of one winding of each such coil *a* neutralizes that of the other; and this is true for direct currents even if interrupted at the highest frequency existing in telegraphy when dots are being sent in rapid succession; but for such high-frequency currents as those of speech and of such small volume, the windings of the coils are practically two independent choke coils in series, offering a maximum inductive barrier.

The choke coils *b* are wound with their windings inductively related, and provide a maximum choking effect. The telegraph apparatus shown is of the usual familiar type, involving a key to be worked by hand, a relay and a sounder. Quite the usual possibilities with reference to the formation of very long telegraph circuits by the use of repeaters are available with these systems, and for the reason that the telephone side of the problem requires long wires of the best known commercial conductor, copper, the telegraph results are excellent.

The foregoing are problems of making telegraphy a by-product of telephony. With so many telegraph wires on poles over the country, it has seemed a pity not to turn the thing around and provide for telephony as a by-product of telegraphy. This has been accomplished, although for the reason that the telegraph circuits are not in pairs, accurately matched one wire against another, and are far from being uniform as to material, it has not been possible to secure as good telephone circuits from the telegraph wires as telegraph circuits from the telephone wires.

The thing which has enabled practical results to be secured is an adaptation of the original principle of different frequencies. A little further study of figure 2 shows that over such a composite circuit, the usual method of ringing from station to station over the telephone circuit by an alternating current of a frequency of about sixteen is practically impossible. This is because of the heavy short-circuit provided by the two choke coils *b* at each of the stations and the heavy shunt of the large condensers. If high-frequency speech currents can pass over these circuits with a very small loss, other high-frequency currents should find a good path. There are many easy ways of making such currents, but formerly none very simple for receiving them. Figure 3 shows one simple observer of such high-frequency currents. It is merely an adaptation of the familiar polarized ringer used in every subscriber's telephone. In either position of the armature it makes contact with one or the other of two studs connected to the battery, so that in all times of rest the relay *a* is energized. When a high-frequency current passes through this polarized relay, however, there is enough time in which the armature is out of contact with either stud to reduce the total energy through the relay *a* to allow its armature to fall away. This may ring a vibrating bell or give any other convenient signal.

Figure 4 shows a form of apparatus for producing the high-frequency current necessary for signaling. It is evident that if a mag-

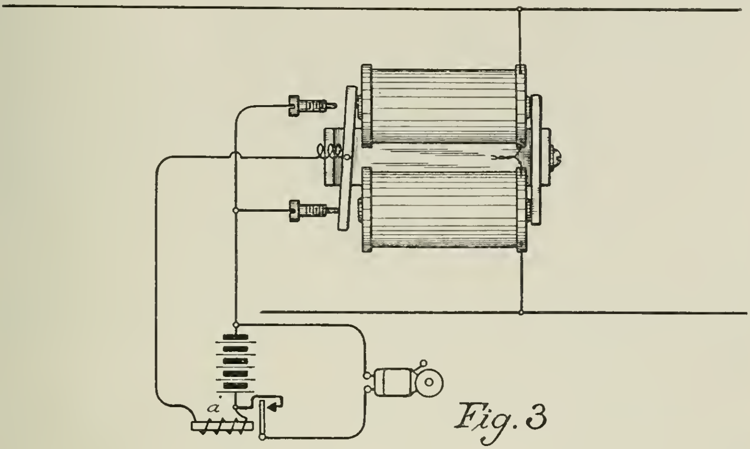


Fig. 3

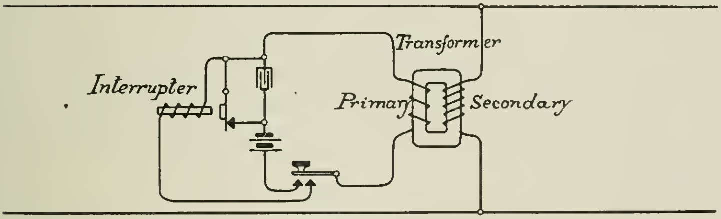


Fig. 4

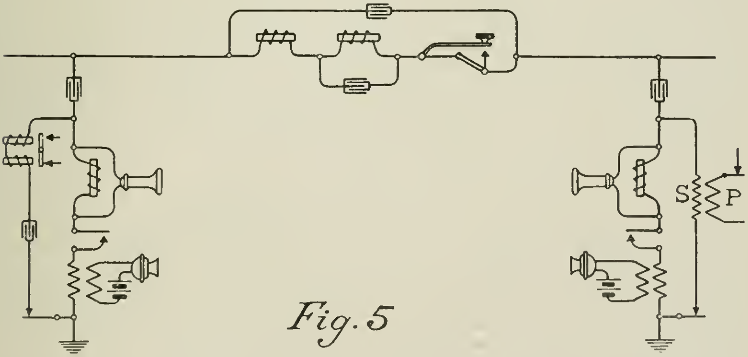


Fig. 5

neto generator such as was formerly used in ordinary telephones, could be made to drive its armature fast enough, it also might furnish the high-frequency current necessary for signaling through condensers, and past heavy impedances. The arrangement in figure 4 is little other than an automobile jump-spark coil, and serves its purpose admirably.

Applying these principles of high-frequency signals sent and received to a single-wire telegraph circuit, the arrangement shown in figure 5 results. The principal points of interest herein are the insertion of impedances in series with the telegraph lines, the shunting of the telegraph relays by small condensers, the further shunting by the whole telegraph mechanism of a station by another condenser. and thus keeping out of the line circuit changes in current values which would be heard in the telephones if violent, and might be inaudible if otherwise. A further interesting element is the very heavy shunting of the telephone receiver by means of an inductive coil. The alternating current sending and receiving devices will be recognized in this figure also.

In telegraphy overland lines, that is, lines across country or in the air, the two things which particularly limit the distance over which communication is possible are the resistance of the wire and the insulation of that wire from others and the earth. In quadruplex and other multiplex systems of telegraphy aiming at the transmission of more than one telegraph message over a wire at the same time the effects of the electrostatic capacity of the wire begin to be noticed. These capacity effects are most noticeable in very high-speed telegraphy, but not so greatly in the simplest forms of sending by hand.

In telephony, however, the effect of the capacity between the two wires of a circuit becomes marked as soon as the line attains a length of a few hundred miles. In telegraphy, repeaters can be used to start the signals on a new circuit, and thus link by link a very long stretch can be covered. No one has invented a practical telephone repeater, so that whatever is possible in the way of applying improvements must be done by making the transmitters more powerful, the receivers more sensitive, or the line better able to carry the current without loss.

IMPROVEMENTS IN LONG TELEPHONE LINES.

In the laboratory one may build a line having a very considerable resistance indeed, and talk over it successfully. In actual practice one may build a line and insulate it very thoroughly, but there is no way of building a line in the air, in the earth, or under the sea in which the dimensions and spacing of the parts of the circuit will be at all reasonable without the resulting capacity between the two wires being large enough to absorb a very considerable part of the transmitted current.

Figure 6 illustrates something of the condition which every telephone circuit fulfills, the condensers shown in the figure being a mere reminder of the capacity which exists across the pair. A line one thousand miles long may have a capacity of seven microfarads, even if the two conductors are a foot apart. Any decrease of this distance of separation or any increase in the size of the wires increases the capacity; the shorter the poles the greater the capacity, and in underground or submarine cables, where the wires are very close together and are insulated with gutta-percha or rubber, the capacity runs up enormously.

The most notable effort in the direction of improving long telephone lines as transmission circuits, is found in the work of Dr. Pupin. His remedy is simply that of inserting inductances at regular intervals in series with the two wires of the line, the effect of these insertions being to neutralize the capacity between wire and wire. As the capacity is distributed uniformly throughout a line of uniform construction, the ideal method of cure would seem to be the insertion of just the right amount of counteracting inductance, also distributed throughout the wire. No one has shown just how inductance may be inserted in this distributed fashion, so that the close approach to the same result, accomplished by inserting inductances in lumps, is a very happy solution of the problem. The practical results of Dr. Pupin's method are a very striking improvement in the volume and quality of received speech. Because of a simple mechanical analogy, circuits so equipped with inductance coils are called "loaded" circuits. Loaded circuits in underground cables are a distinct success, and that method is the best known one for improving long underground circuits, principally useful in trunk lines between the offices of a large city system. The improvement possible by inserting loading coils in long lines on poles is not so great as in the case of underground circuits. This difference in the respective improvements is due to the lower capacity and larger self-induction of the open-wire circuits. Under the best conditions, transmission over the latter is distinctly improved, but in seasons of wet or foggy weather covering most of the territory traversed by the line, a very large part, if not all, of the advantages of loading are offset. When a means has been found of distributing the inductance throughout an insulated conductor and of placing such a pair of telephone wires cheaply and easily in the earth, where insulation will remain constant, it is conceivable that much greater distances may be covered than are at present available.

Certain submarine telephone cables extending between Denmark and Sweden are provided with pairs in which each conductor is covered with a spiral wrapping of soft iron wire, the object being a similar neutralization of the mutual capacity. It is reported of these cables that their success is marked, and that the manufacturers accepted specifications which called for quite a definite performance, the results bearing out the expectation in a large degree.

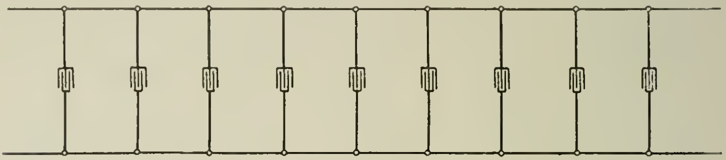


Fig. 6

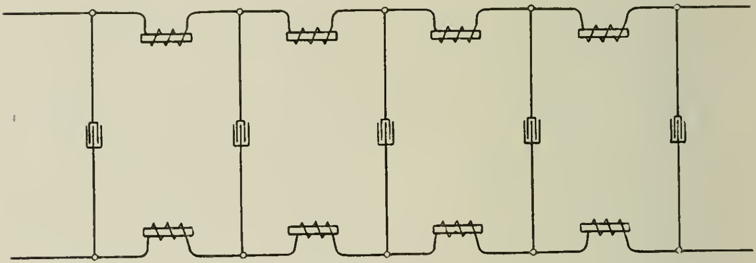


Fig. 7

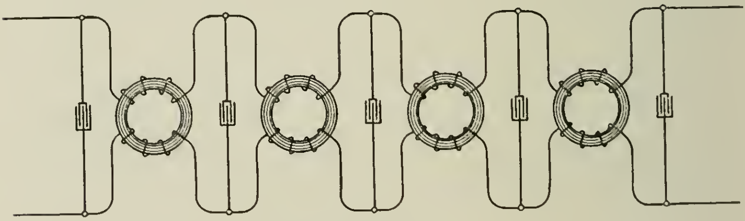


Fig. 8

Figure 7 illustrates the Pupin method of inserting inductances, the condensers in this figure, as in figure 6, serving as a mere reminder of the distributed capacity which it is the function of the coils to overcome. In actual practice, the loading coils are of the form hinted at in figure 8, each coil having two windings, one for each line wire, these two encircling the same iron core. The wires of the core are very small, very soft, are insulated with a very thin compound, and the cores are ring shaped or toroidal.

LONG DISTANCE TRUNKS.

In all but the smallest communities there are enough lines of local subscribers to be switched together to require the service of more than one operator, and in such offices, unless they are very small, it is expedient to provide separate operators for the long-distance lines. In the largest communities, the lines of local subscribers are grouped in several offices, each serving its own district. Trunk lines connect these several offices for enabling any subscriber to talk to any other in the same city. One office suffices for all the long-distance lines entering such a city, and from that office trunk lines extend to the various subscribers of the local exchange proper.

These things being so, it is necessary that the subscribers have facilities for making their wants known to the long-distance office, and that the latter have facilities for calling up any subscriber wanted by a distant point. The former is accomplished by trunks leading direct from the local branch offices to special operators whose duty it is to write tickets for these calls. The latter is accomplished by means of trunks leading from the operators serving the long-distance lines to special operators in the branch offices, these having the duty of connecting those trunks with desired lines in the switchboard. It is the latter which are used for all actual conversations between long-distance lines and subscribers.

A comparison between figure 9 and figure 10, will bring out the simple but important feature that whereas in figure 9 is illustrated a typical connection between two subscribers having lines in the same local branch office, figure 10 illustrates a connection from a subscriber in one office through his own and a distant office by means of a trunk line. The feature of importance in figure 10 is that the current to energize the subscriber's transmitter is furnished to him over his own line from his own office.

Carrying this last and important point further, it is instructive to note that the same feature is utilized in trunks from a long-distance office to a branch office. The called subscriber must receive current for his transmitter from the nearest possible central office, and naturally that is the office of his own district. It is further of advantage that, when he is called up over a special trunk line from the long-distance office, the operator who called him be able to ring his bell when she may choose to do so. She may need to repeat a call or may need to delay one until the distant subscriber is at his telephone. The mechanism which accomplishes the happy result of supplying transmitter current from the nearest office stands in the way of successful ringing over the line in the ordinary manner. Figure 11 illustrates as simply as possible the "ring-through" feature. Ringing current applied to the trunk wires *a* and *b* energizes the relay *c*; the armature of this relay in turn causes current from the battery B to energize the relay *d*. This relay is merely an electrical ringing key, and does the same thing as would a manual ringing key, in that sixteen-cycle current is sent to the local line from the generator *e*.

It will be seen that the cycle of events is the application of low-frequency ringing current, which controls the sending of direct current a short way, which controls the sending of low-frequency ringing current on to the called station.

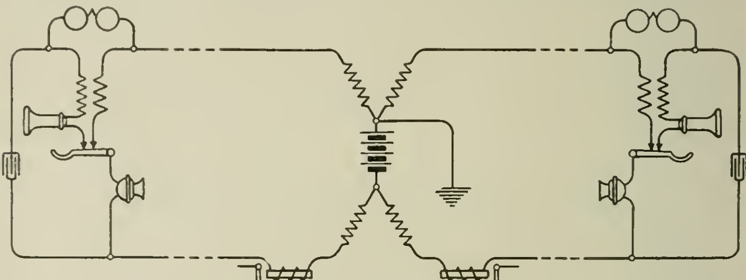


Fig. 9

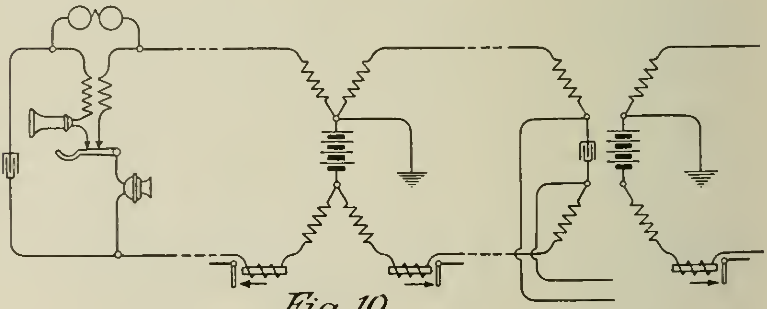


Fig. 10

In actual practice the circuit shown in figure 11 is accompanied by many other elements having to do with local signals, busy test, etc., but like many other circuits, the apparent complication is accompanied by a surprisingly simple and accurate operation.

Even from figure 12 many further elements have been omitted, but enough remain to illustrate the conditions of connecting, conversation, supervision and disconnection in a circuit from a long-distance line to the switchboard containing the called subscriber.

"BOOSTER" BATTERIES.

When the principle of supplying current for transmitter purposes from the nearest office has been fulfilled, a highly satisfactory local transmission is secured, even over lines of several miles length and several hundred ohms resistance. To enable the fullest advantage to be taken of transmission from these lines over the longest country circuits every minor assistance must be captured. With a given construction of transmitters there is a critical maximum current which can be carried by the granular carbon of the instrument without excessive heating and consequent noises and permanent damage. The shortest lines and the longest lines being served by one source of current common to all, the potential of this source must be such as to give the longest lines current enough without giving the shortest lines too much. The very longest local lines, however, are in those systems prevented from getting enough current for the maximum efficiency when talking over long-distance lines, although they are getting enough for local conversations.

The circuit shown in figure 13 offers a happy solution of this difficulty. When it is understood that the circuit is intended to be used for current supply in a trunk between long-distance and local lines and that the battery B has a voltage of say fifty volts, or about twice that used for local conversations, and that the elements *r* are resistances, it will be seen that by a proper proportion of these resistances to the other things previously mentioned, just enough current may be given to the shortest lines, and quite a little more than under standard conditions to the longest lines.

"TICKET-TUBE" SYSTEM.

When only one operator is necessary in a town, all lines, both long-distance and local being switched by her, she may write her own tickets and execute them for all communication between long-distance and local circuits. As the community and its business grow, a condition is reached in which there may be many long-distance operators and many more local operators, and the former will need to be specialized as to their particular duties. In the largest offices, as I have indicated, the wants of the subscribers as to long-distance connections are sent in by telephone, written out on tickets, and these passed to operators who get the parties together. The problem of ticket passing so becomes important, and many ways have been practiced, culminating in the system which utilizes vacuum tubes carrying the ticket directly without any enclosing case. Figure 14 indicates the elements of such a system, the distributing table being one at or near which the tickets are written, and from which tubes lead to all of the regular connecting long-distance operators. Suitable means maintain a vacuum in a large common tube, having a tap to a box-like valve at each such operator's position. The tickets are of uniform size, and are so scored in making as to enable a flap to be bent up easily along the edge. The distributing operator has merely to insert the ticket, flap foremost, in the open end of the tube, whereupon the air pressure behind it will drive it through to its destination, which may be near by or far away, on the same or another floor of the same building or another. The speed maintained by the tickets in practice is thirty feet a second. The tubing is rectangular in section, as shown, and by the exercise of much invention, it is possible to form the tubing as may be desired, the flat and edgewise bends shown in figure 14

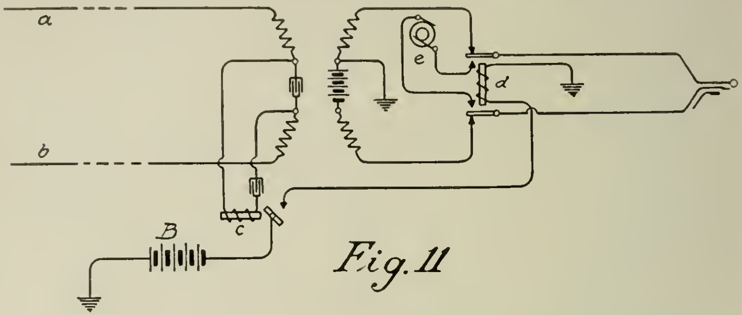


Fig. 11

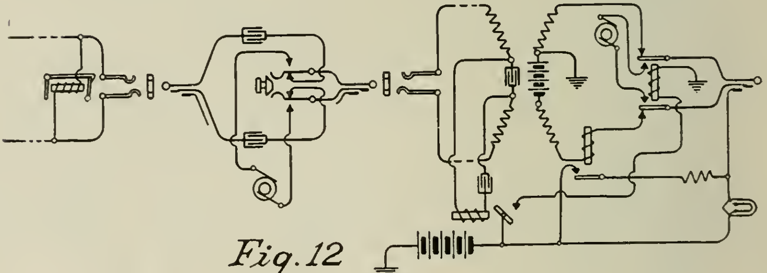


Fig. 12

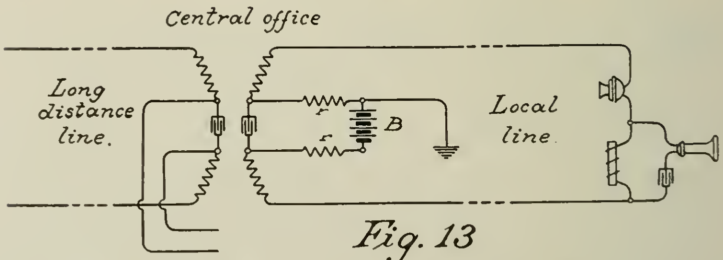


Fig. 13

being not long ago quite impossible to make from the straight stock.

Two springs in the receiving valve are normally in contact. The arrival of a ticket between them breaks a circuit, which removes a shunt from a relay. This relay in closing lights a lamp, which calls the operator's attention to the ticket's arrival.

Some one has said there are only two things about a man which matter very much: "Who are you?" and "What do you do?" *Getting results* is what counts. The results I have tried to describ in the foregoing, simple as they are in method, show good value when measured up against the commercial effects they have produced. But if all the people are to have the benefits now available for the few, several things must be provided and these are some of them:

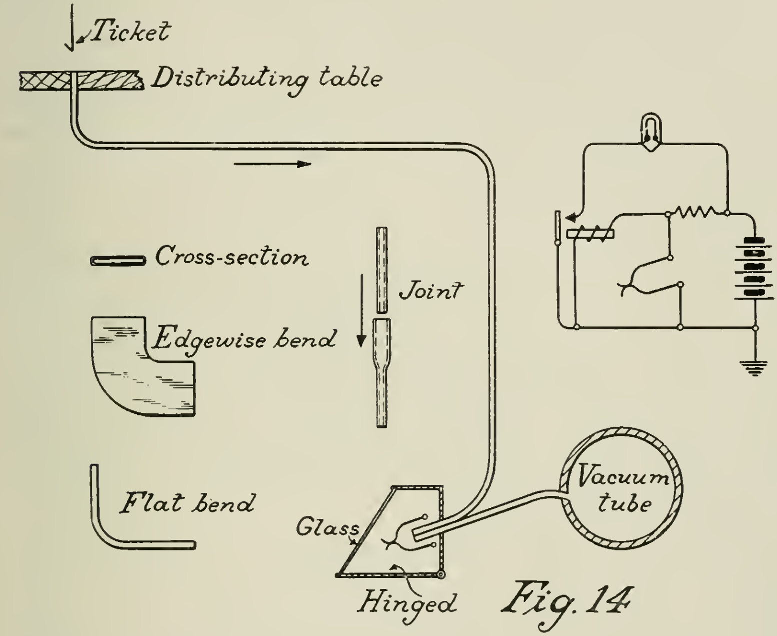


Fig. 14

Cheaper line circuits.

A successful telephone repeater.

More powerful transmitters.

Multiplex telephony.

Any one of these improvements will advance the art. A multiplex system will provide a cheapening of the line circuits. A repeater or a more powerful transmitter will increase the possible radius. There are still acres of diamonds undiscovered.

DISCUSSION.

Mr. Thomas D. Lockwood—I suppose that it is the proper thing always to begin a discussion by saying that the speaker has so well covered his subject that he has left nothing for any one else to talk about. I will leave it to you, however, whether he has not said what he had to say, well, barring perhaps, his reiterated statement occurring at intervals of about 10¼ minutes that "this is true." I think he might have let us take that for granted, because by emphasizing the fact that certain portions of an address are true, we are irresistibly conducted to the conclusion that the rest of it may not be true. I do not like to leave my friends in doubt, and will say that *most* of what the speaker has said is true.

It is difficult to discuss a paper like the one presented to-night; first, because we have not the paper printed before us; partly because very few are in position to seriously dissent from anything that was said; and partly because the subject, to a greater or less extent, is trite.

The Chairman's introduction of my humble self reminded me of a little story—an early experience of my own at a prayer-meeting. The minister was not there and a deacon was invited to preside. This deacon was in the habit of referring to his own efforts as "feeble remarks." It is barely possible that some of the gentlemen here have been to prayer-meetings, and, if so, the expression "feeble remarks" will not be altogether unfamiliar. But this gentleman was so accustomed to referring to his own efforts as "feeble remarks" that in his capacity as leader he asked Brother Smith to make a few "feeble remarks."

Now, any remarks I may have to offer on the subject of telephony must necessarily be feeble, because I cannot remember much about it. I suppose I am one of the oldest telephone men in the world in experience, and I certainly was much interested in hearing this account we have heard to-night of the progress of the art, which I, myself, remember in its beginning. A great patent lawyer once said: "I approach a dynamo with a certain amount of reverence and a great amount of fear, realizing that if I touch it perhaps it may touch me. I know something about the electric telegraph, but with the telephone in my house I can call up and talk with my friends seemingly face to face; I can listen to what they say to me, and feel that the very slight vibrations of my voice are making vibrations throughout a great length of wire. In such circumstances I realize that though one may not 'by taking thought add one cubit to his stature,' Professor Bell, by 'taking thought,' has added not one cubit, but many hundred miles to the lengths of our tongues and ears." Professor Bell was perhaps the man best fitted of all to take up this work, and he was taught by his father from a very early age—when he was scarcely 13 years old—that idea of making dumb people and things talk. He, therefore, was the very man to apply that method in making plates of iron talk, and I think that is one of the greatest wonders in all the world. It takes the combined effect of our lips, tongue, larynx and lungs to produce articulate speech, yet the little iron plate in its vibrations can do the same thing. That which we hear in the receiving telephone is not, after all, much like perfectly articulated speech. I grieve to say that neither are the articulated utterances of many of us. How often is it, listen as we can, that we have to beg a man's pardon for failing to understand what he says to us, when he really ought to beg ours for his poor enunciation; and so I think that the best reproduction of speech in the very best telephone is after all rather an imperfect copy of the speech which was offered previously; but we know what is to be expected, and so, just as we read the uncommonly bad writing of the average bank cashier and know what he has written, just so we read with the ears of our mind what is coming, and understand what is said when the speaker does not in fact say anything very much like it.

I was glad to see in many of the pictures the product of my own mill. I take that as a most sincere compliment, for when a man like Mr. McMeen, wanting to illustrate his paper, takes many of the drawings which are in patents which I have written, I admire his taste. I was pleased to also recognize certain words which I had coined. I believe I was the first person to ever speak of a "composite circuit." It is not a good name, but it has come to stay; and it after all is better than some modern terms, the word "booster," for instance. Then there is the term "repeating coil." I noticed that Mr. McMeen does not quite like that phrase, as he sometimes calls it "repeating coil," sometimes "induction coil," etc. But I suppose, after all, it is nothing more nor less than an induction coil, and that term is not at all inappropriate. I particularly indorse Mr. McMeen's remarks on repeaters.

Long distance telephony is not a modern thing. In October, 1877, the first long distance circuit was erected, and the next week there was a talk between Boston and New York (there were no copper wires); no one knew then exactly what to expect from the telephone, though that telephone, which had a magneto transmitter as well as a magneto receiver, worked quite well.

Referring briefly to inductive disturbance, I recollect that in September, 1879, there was an agent of the telephone company at a place called Bradford, Pa. He had a line about 30 miles long between Bradford and Richburg, and he wrote to headquarters in Boston inquiring what he should do, because that line was such a noisy one, and I, being the working side of the department, wrote him a letter in reply to the effect that if he would put up a metallic circuit much of the disturbance would disappear. This gentleman, being of an economical turn of mind, thought, in doing this work, he could get more for his money by including a larger area of territory; this he did at great expense, and then wrote back that the noise was worse than before. What he had done was to provide another wire, but carrying it over another route to include other towns he so exposed both limbs of the line to different sets of disturbing causes that the intended remedy merely intensified the trouble.

I think we may acknowledge that there are several reasons why a metallic circuit is good. When inductively neutral metallic circuits were first put up in great quantities, a great many of even experienced telephone men thought that was going to eliminate all kinds of telephone disturbances. They quite forgot that every telephone line had two sides, and that side No. 1 of circuit No. 1 will act upon side No. 1 of circuit No. 2, and side No. 2 of circuit No. 1 will act upon side No. 2 of circuit No. 2; and so, while the metallic circuit did take out much of the noise, it did not take out what is called "cross-talk"; that is why transpositions had to be introduced, and those transpositions are another remarkable invention. They were not first invented on this side of the ocean, although I believe that it was here that they were first made practically available.

Mr. F. R. McBerty—I wish to touch upon a point on which Mr. McMeen did not assure us he was telling the truth; that is, the nature of the cores of the loading coils. The statement was made that the wires of the core are very small and very soft. The wires are very fine and are insulated, but are not soft; the wire is steel and quite hard, the reason being that hysteresis losses in wire of high permeability are large.

Another point in connection with loading coils I will mention because it will be of interest to some of our light and power friends, as perhaps presenting a somewhat novel though not entirely new phase of alternating current power transmission; that is, the reflection at points where the inductance of the line changes in amount. The speaker referred to the losses from change in the insulation of the line. A much more serious source of loss in some lines is this: Wherever the inductance loading of the line changes abruptly, as it does in repeating coils, terminal apparatus, cables, etc., a reflection of the electric wave takes place. Where long distance lines have to be connected to subscribers' stations, reflection may occur at different points along the line, and may vary as the trunk line becomes connected to different subscribers' lines. There is no way of calculating all possible conditions to permit adapting the circuits to the sub-station apparatus. One of the patented arrangements for taking care of this is what is known as the terminal taper, in which the inductance of the loading coils across the line is reduced gradually from the inductance corresponding to sections of the loading line to a low amount, so that as there is no abrupt change the reflection does not occur. You are familiar with the acoustic analogy that a sound wave beating against a solid wall is reflected; but a sound wave beating against a wall of felt, which is soft and permits of some vibration, is not reflected to an equal extent, and the wave does not suffer in the same way. The condition is somewhat analogous.

Another point the speaker mentioned was the value of an increase in the efficiency of transmission or of a repeating relay. I should emphasize the value of such an improvement even more than he did. There is a zone within which long distance transmission is known to be possible, and within that area transmission is practicable and reliable; people are disposed to use the line as they need it, and they always pay for it. Then there is the zone with the problematical conditions, depending on the weather, etc.; within that zone transmission may be good one day and bad on another, the service being sometimes first class and sometimes otherwise. Experienced users are unlikely to attempt transmission within this zone excepting in urgent cases, and when they do attempt it are likely to get such poor service that they will refuse to pay for the connections. Beyond that zone, beginning at an indefinite point, lies the area within which transmission is supposed to be impossible. Connections extending into this outer zone are more likely than not to be unsatisfactory. In the two last mentioned cases, however, a considerable percentage of the connections represents a loss to the telephone company. The customers are dissatisfied with the result; their experience deters them from making more calls within the same zone and also may make them hesitate to use the telephone for even shorter distances. Unsatisfactory conversations are likely to be of greater duration than satisfactory ones, while at the same time the maximum value of plant is being occupied; and, finally, the customer is likely to refuse to pay the charge, or to consent to pay only a part of it. If the telephone companies knew definitely where the limits of these zones were, they might limit the connections so as to get the maximum revenue of every plant, but they do not. The area which can be covered by the transmission you will see increases as the square of the radius, so that on one day it may be possible to reach a vastly greater number of telephones than on another.

Any changes in telephone apparatus at the sub-station or in the central office which will define the limits, as well as any which will extend them, will be of substantial value.

Mr. Kempster B. Miller, M. W. S. E.—There is a point that suggests itself to my mind as being a factor that will tend to decrease very materially the value of telephone facilities between points widely separated by longitude; that is, between points a great distance apart with respect to east and west. Where there is a difference of several hours in time between the two ends of the line, as would be the case in a long line running east and west, it is obvious that the people at one end may be in bed while the people at the other end are indulging in their greatest business activity. This would, of course, tend greatly to decrease the traffic over such lines; much more so in the case of the telephone than in the telegraph, because the telephone is a means for communication between principals, whereas the work of communicating over telegraph lines is almost entirely performed by employees. Employees may be paid to stay up at all times of night, while those who employ, and who would therefore use the telphone, will not. So the long distance telephone transmission will lose in effectiveness by differences in point of time between its ends than will the telegraph. Transoceanic telephony, if ever that is achieved, would undoubtedly suffer much, due to this cause.

About repeaters, I remember reading, a few years ago, a paper by Mr. Lockwood, in which he said it was perfectly possible to make a repeater that would talk between distant points; and Mr. Lockwood went on to say that these repeaters would transmit speech almost as well as if no repeater had been used and the transmission had been direct. All of us who have dabbled in telephone repeaters, and I think there are few telephone men who have not, have probably achieved a degree of success quite as satisfactory as that mentioned by Mr. Lockwood. It occurs to me that the direction in which we must look for a successful repeater is in the line of the reduction of the mass and of the inertia of the moving parts. In this connection the work of Cooper-Hewitt seems promising, and at any rate is very interesting. He finds that, by subjecting a tube containing his mercury vapor to varying magnetic influences, the resistance of the path through the vapor is altered, the alterations in resistance being in accordance with the changes in the magnetic field in which the tube lies. Here he has the fundamental elements of a telephone repeater, and, and working as he does with a gas—and a highly rarefied gas at that—it seems that this scheme, or one like it, might be productive of good results. A very different form of repeater was proposed by Erdmann several years ago, when he used an electrically operated valve, which served to vary the pressure of a rapidly moving current of air. The valve responded in its movements to the variations in voice currents, and therefore altered the pressure of the air, which, acting on a diaphragm, produced movements of the variable resistance transmitter parts to bring about current variations in the second part of the line. I understand that this has not been productive of good results.

Mr. C. S. Winston—I am very much interested in long distance transmission, but particularly in regard to what the speaker said about composite work, as during the last few months I have been more or less associated with some experiments along that line. We have been trying to get up an arrangement similar to the one he spoke of, using a polarized relay so that while a line is being used for telegraphing, a signal could be given whenever it is desired to use the line for telephoning, without interfering with the telegraph apparatus.

For the purpose of experiment we constructed a polarized relay similar to the one described by Mr. McMeen, but much smaller than any that has ever been used for work of this sort, as far as my knowledge goes. It was our desire to use apparatus which could be put into a magneto telephone. The cores of this relay were little, if any, more than three-fourths of an inch in length, and the results which we obtained were too good; that is, we found that, while the signal was given perfectly, yet the voice currents were strong enough to operate and thus give the signal when it was not wanted. This, of course, would cause a great deal of trouble in case more than two stations are placed on one line. We found out incidentally during the course of our experiments that if this relay, which was bridged between condensers across the line, was opened at one terminal and so connected to one side of the line only, it would still operate during conversation.

I think that in the future there is going to be a great many of these composite circuits put into use, in country districts especially. This class of service will need only the simplest form of composite circuits, those used in repeating coils or condensers, and it is probably a good thing, as the men who have charge of country telephone lines and country exchanges have not sufficient knowledge of the business to take care of the comparatively complicated composite lines. My reason for forming this opinion can be best illustrated by an instance that came to my attention two or three years ago. The manager of a telephone exchange in a western town changed his local battery system to a common battery system, and for a while after the men who installed the switchboard left things went smoothly, but only for a while. Then troubles began to appear, and he began to call on the manufacturers for help. One day a letter came from him, in which he stated that he was having some trouble with certain lines which he was unable to solve; that the subscribers could signal the board, talk to the operator, and after the connection was established begin a conversation with the person desired, but very often their conversation would be interrupted, a disconnect signal would be given at the board, and they would be entirely cut off from it. A letter of considerable length was written to him (I am glad to say I did not write it) in which several very learned possibilities were given. A day or two afterwards he wrote another letter in which he stated that he had found out the cause of the trouble in a peculiar way. To use his own words, "The trouble happened on a line about 100 yards from the exchange. I skinned right over and found the ——— fool with his elbow on the telephone hook trying to talk. After this all that will be necessary for me to do will be to tell them to 'keep off the grass' and everything will be all right."

Mr. Hale, M. W. S. E.—In view of the fact that Mr. Hibbard and Mr. Wray, of the Chicago Telephone Company, are not with us this evening, I think I may venture to tell a little story:

Some time ago, upon being shown a curve illustrating the variations in volume of telephone service throughout the day in this city, I observed that the curve displayed the usual fluctuations, with a morning maximum at about 11 o'clock, and an afternoon maximum between 2 and 3. After 3 o'clock the line descended uniformly until 5:30, when there was a sudden rise. Wondering at this, I asked one of the Chicago Telephone Company's courteous and able engineers, "What makes that hump?" "Oh," he replied, "that is made by the married men of Chicago who call up their wives between 5:30 and 6 and try to explain just why they cannot be home to dinner!"

Mr. Lockwood—I remember noticing that one of the terms used by Mr. McMeen in reference to the loading coils was "toroidal." That term is doubtless familiar to many, but may not be familar to all, and I think it would be a very good thing if Mr. McMeen would explain to us exactly the meaning of that term. When I first heard it, it was entirely unfamiliar to me; and I think it is always best to explain such terms, for the benefit of the possible two or three who do not understand them.

While I am on my feet I wish to say how extremely gratified I have been in listening to everything in the paper, and with the extremely delightful and happy manner with which it was read and explained.

Mr. Miller—There is a feature connected with the commercial manufacture of those toroidal coils that occurs to me as being a difficult one. I refer to the method of winding them. Coils wound on a permanently closed magnetic circuit, as in the toroidal core of these coils, are not susceptible to the ordinary methods of winding for obvious reasons. I confess ignorance of any method of winding these coils rapidly by machinery, and suppose, on account of the large quantities in which they have been manufactured, that some very ingenious machine must have been devised for the purpose. If it is not asking for the giving away of state secrets, I suggest that Mr. McBerty tell us something about the winding of these toroidal coils.

Mr. McMeen—I rise in response to Mr. Lockwood's question. There are several ways by which I might avoid answering it; one is that I might decline to give the definition because I did not know. But toroidal really means "after the maner of, or like, torus." or, in other words, toroidal means shaped after the manner of a doughnut "like mother used to make"; not twisted, but round, with a hole in it. The cross section is an ellipse. Toroidal, then, means ring shaped, elliptical in cross section.

Mr. Lockwood—Yes, but the core must have a circular or cylindrical cross section.

Mr. McMeen—The important point still remains, that, without regard to the shape of the coil, it is just as difficult to wind by machinery such a core with wire, whether elliptical or circular. The first coils were wound by hand, but they are now wound by machinery. The core is of wire insulated with a material not fibrous, and is composed of many turns of fine wire. The only reason I made the mistake of saying the wire was soft is because I did not know. As to the machine that does the winding, to which Mr. Miller refers, it is a very ingenious affair, and I think Mr. McBerty ought to tell something about it, as suggested by Mr. Miller.

Mr. McBerty—The machine is somewhat difficult to describe briefly and would be more difficult to draw; but I will outline the principle. Imagine a toroidal core in a horizontal plane and a winding spool interlinked with it, the spool having a deep channel turned in its outer periphery to hold the wire to be wound on the core. The spool has a removable segment, which, when taken out, permits the linking together of the core and the spool. The removable segment is held in place by screws. The spool is supported on three roller so that it can be rotated in its own plane, the section of the toroidal core coinciding with the center of the spool. The removable section is removed, the core and spool are linked together, and the removable section is replaced; then the channel in th spool is wound full of wire by rotating the spool in one direction. The extremity of the wire is attached to the toroidal core and the spool is again rotated, unwinding its contained wire about the core, laying one turn on the core for each rotation of the spool. There are some attachments for holding the toroidal core, rotating it through small arcs to cause the windings to be laid on smoothly, and after taking up the slack of the wire paid off from the toroidal spool.

Mr. Watkins, M. W. S. E.—I would like to ask Mr. McMeen just why the term "loaded" is applied to a circuit containing inductance coils?

Mr. McMeen—In Dr. Pupin's patents, either the one covering the method, or that covering the apparatus, for the insertion of inductance at determined points in order to eliminate the hurtful effects of the capacity across the circuit, the mechanical analogy of a vibrating string is used in conjunction with the specification to point out what phenomena appear in the circuit while in use. You will see, easily, that a light string of some length, one end being tied to a support and the other held in the hand, may be shaken at one end to the production of waves which pass from the hand to the support. Whatever energy is put into the string will suffer a large loss in transmission to the support. If the string have added to it weights such as leaden bullets at certain intervals, a continued addition of such weights interspersed with experiments will make plain that less loss occurs in the waves in the case of the loaded string than in the case of the unloaded string.

I think this will answer your question as to the fitting use of the term "loaded."

Mr. Edson—There is one question I would like to ask, and that is this: If we build a long line—about 500 miles—and that line begins to grow, and we have one pole line with 30 or 40 circuits and have to run others, keeping on building, to what point will it be more economical to put in a cable and get better service? That is a question that is going to come up in the future. After a while we will get our large centers occupied with a great network of very expensive overhead wires, and some day we will have to put those circuits under ground and maintain them more economically. Now the question arises, what point in the overhead construction will it be more economical to put in an underground cable between certain points, say 400 or 500 miles?

Mr. McMeen—The Chairman ought to answer that question. My own opinion with reference to that ultimate condition to which you refer is that in somebody's lifetime those wires, when in such quantities as you indicate, must go underground, for a number of reasons. Placing wires up in the air on sticks is some day going to be considered crude, and it is expensive. The wires must be large enough to hold themselves up. I feel very sure that the conductor of the future will be a wire containing a distributed inductance just sufficient to counteract the mutual capacity of a pair of such wires in place.

Your question is quite in line with the phase of the subject which I treated in the paper, without any such expansion as the gravity of the situation really requires. The costs of contral office equipments and the instruments used at the ends of the lines, while great enough in total, are relatively insignificant when compared with the very much larger costs of the plant lying out of doors on poles and in the ground. The real problem which must be faced by all economists in telephone engineering is that of so modifying this out-of-door material as to get lines of greater efficiency at very much smaller cost per unit. As matters stand to-day, for the reasons we have touched upon, the line wires must be of considerable size and be maintained a considerable distance apart. When the short-circuiting effect of the capacity, which we have harped upon so much, has been greatly reduced or wholly eliminated, the size of the wires may be made less, the conductors of a pair may be much closer together and the whole structure will be placed underground where maintenance and depreciation charges will be least and the usefulness of the whole structure most remarkably extended.

MEASUREMENTS OF UNDERFLOW STREAMS IN SOUTHERN CALIFORNIA.

PROF. C. S. SLICHTER, M. W. S. E.

MEASUREMENTS AT THE NARROWS OF THE RIO HONDO AND SAN GABRIEL RIVER, CALIFORNIA.

These underflow measurements were made at the narrows of the Rio Hondo and the San Gabriel River, about ten miles east of Los Angeles, California. The ultimate source of these streams is found in the San Gabriel Mountains, a range which runs nearly east and west about forty or fifty miles from the southern coast line of California. The main portion of the mountain drainage which supplies this particular stream is collected into one of the larger cañons of the range, known as the San Gabriel Cañon. Like other streams that originate in these mountains, the water is not carried above ground much further than the mouth of the cañon, except in times of extreme flood. The ordinary flow of the river sinks into an enormous alluvial delta-cone of gravel and mountain debris, and passes underground in a broad, gently sloping valley until it is interrupted by a line of shale hills about ten miles south of the mountain range. This line of hills acts as a dam to the underground waters, except for a break about two miles in width where the drainage of the valley is allowed to escape to the sea. This break constitutes the so-called "narrows" of the river. In consequence of the narrow outlet, a large quantity of the groundwater is brought to the surface, first showing itself about two miles above the narrows, and increasing in volume as it enters the contracted part of the pass. At the present time, the surface waters appear as two distinct streams, the Rio Hondo on the west side and the San Gabriel River on the east side of the narrows.

In 1900, the flow of the Hondo at Old Mission Bridge was 23 second feet; the flow of the San Gabriel is somewhat larger. The observations at Whitney Bridge would indicate that the groundwater and surface waters are substantially identical.

The measurements of the rate of underflow were made by the writer's electrical method, described in the Engineering News for February 20, 1902, p. 151, and in Water Supply and Irrigation Paper Number 67 of the United States Geological Survey, p. 48. The wells used were two-inch drive wells with 42-inch points and 48-inch well point extensions. The wells were usually arranged in groups of four, one well up stream designed to receive the electrolyte and three wells down stream arranged two feet apart on an arc of a circle of four foot radius. Usually the electrolyte moving with the groundwater would show itself at but one of the down stream wells, but in one or two cases it reached two of the down stream wells and in a few cases the first setting of the wells did not correspond to the actual direction of the water-flow so that the lower wells were not touched at all by the dissolved electrolyte.

Measurements were made at four stations located within the narrows of the rivers named. At the first station, two groups of wells were driven under a wagon bridge over the Hondo near the Old Mission. The electrical current was observed separately for a circuit between the casing of the upstream well and the casing of each of the downstream wells, and also for the circuit between the casing of each downstream well and the brass-rod electrode contained within it. If the upper well be called A, and the lower wells be called B, C, and D, the first of the circuits, referred to above, would be designated in the notes "Case B," "Case C," etc., and the second kind of circuit was entered as "Electrode B," "Electrode C," etc.

The velocities at the first station were 3.8 and 6.6 feet per day. The direction of flow departed slightly from the direction of the surface river, the direction at the first location being south 10° west, and at the second location about 15° west of south.

In the second location, the electrolyte showed itself at both of the down stream wells, being stronger, however, in well F. Points of special interest are the several steps in which the ampere curves rise, as shown on the electrode circuits for both wells E and F. These indicate different velocities of ground water at different strata penetrated by the wells. The well points and well point extensions being covered with perfectly new, bright brass gauze in these first tests, the different porous strata would register themselves on the brass gauze by blackened bands caused by the electrolyte. In the present case there were three distinct zones marked off on the wells of about 24-in., 20-in., and 8-in. each. The velocities in these strata undoubtedly differed from one another and, hence, caused the steps in the ampere curve. At both locations at station one, the ground-water was artesian in character, rising in the wells about an inch for each additional foot increase in depth. The wells were 16 ft. deep and showed about 15-in. of artesian head above the water in the flowing stream.

The second station was established on the San Gabriel River, just below the wagon bridge on the Whittier road. A special point of interest at this location is the fact that the river totally disappears in its gravel bed a few rods below this bridge. We hoped to secure some facts concerning the direction and velocity of the disappearing water. A double row of wells was driven across the river bed in three groups about 33 feet apart. All of the wells except a group near the left bank pumped very poorly and were evidently in very tight material. The group of wells near the left bank consisted of one up stream well, E, and two down stream wells, F and G. These wells evidently penetrated two different strata of water, as a velocity of 48 ft. a day was observed between E and F, while a second result was strongly developed, indicating a velocity between E and G of 4.8 ft. per day. This latter rate was due to the lower stratum of water whose direction of motion crossed at 35° that of the upper current of disappearing river water. Further observations at this point were rendered impossible by the breaking of a dam some distance above the station, which completely flooded the wells after the above observations had been made.

The third station was established in a walnut grove on Temple's ranch, near the main road from El Monte to Downey. This location is about half way between the two bluffs of the narrows. The group consisted of four wells and the velocity was found to be quite low, 14 in. a day. The direction of flow was due south.

The fourth station was on the bank of the San Gabriel River, just above the head works of the Ranchita and Los Nietos ditches. The velocity determined was 5.6 ft. a day, in a direction due south, making an angle, however, of about 45° with the direction of the surface stream at the same point.

The cross section of the alluvial deposits at the narrows of the Hondo and San Gabriel is about 10,000 feet wide and probably does not exceed 600 feet in depth.

If we assume that the porosity of the underflow gravel is 33 per cent and that the average velocity of the ground water is 10 feet per day, the resulting estimate of the amount of water which passes underground through the narrows is 230 second feet, or nearly four times the flow of the surface streams. This is undoubtedly a maximum estimate, as there is no indication that the average velocity is as high as 10 ft. per day.

Four feet per day may be assumed as a fair minimum value of the average velocity. This would correspond to a total underflow of 92 second feet.

The above measurements established the existence of a distinct underflow of moderate velocity through the alluvial deposits of the narrows. In low stages of the surface streams the underflow probably represents a drainage from the upper valley in excess of that discharged by the surface streams. The substantial identity of the water of the underflow and the water of the surface streams is proved by tests at the Whitney Bridge as already noted, so that we may conclude that the original mountain stream appears at the narrows as a composite river, consisting of surface streams bordering both the east and the west bluffs of the narrows, together with a very wide and deep but slowly moving underflow stream occupying the entire major trough of the valley.

MEASUREMENTS AT THE NARROWS OF THE MOHAVE RIVER NEAR VICTORVILLE, CALIFORNIA.

The Mohave River rises on the slope of the Sierra Madre Mountains in San Bernardino County, California; the head waters flowing from elevations of from 5,000 to 8,000 feet. After following a general northerly course the stream disappears in the Mohave desert a short distance below Barstow, Cal. After leaving its mountainous cañon the stream gradually loses water and for a large portion of the summer its bed is dry for a greater part of its course on the plains. At a point about sixteen miles north of its source, the river passes through a narrow gorge called the "narrows" of the river. The granite uplift which forms this gorge constitutes a dam which raises the underflow to the surface, so that a mile and a half above the gorge to a considerable greater distance below the gorge the stream is of perennial flow. This gorge is just south of the village of Victorville, California, a station on the Santa Fe railway. The place has been under investigation as a possible site for a dam by the United States Geological Survey during the season of 1899 and previously. Reports will be found in the Eighteenth Annual Report, United States Geological Survey, Part IV, p. 708, and the Twenty-first Annual Report, United States Geological Survey, Part IV, p. 471. The permanent dry season flow of the river at the gorge varies from about 30 to 60 second feet. On August 15, 1902, the discharge as measured by J. B. Lippincott was 33 second feet. Soundings have been made to bed rock at three different lines across the narrow part of the gorge, by the U. S. Geological Survey. The position of these lines are shown in the reports above referred to. The river gauge rod of the U. S. Geological Survey is located on the right bank of the river at the end of line 3, which was selected as the location for the underflow measurements. The maximum depth to bed rock at this point is 46 feet, as is shown in the approximate cross section given in Fig. 11. The material filling the gorge and constituting the bed of it is a coarse angular granitic debris of a size somewhat larger than buckwheat. Determinations of the effective size of the gravel by King's aspirator showed a mean diameter of 0.72 mm. The samples of gravel were taken from the surface material. High velocities of the underflow determined at certain depths indicate that there are some streaks of coarser material.

The site selected for the measurement of the underflow at the upper narrows of the river was in a line extending across the river at right angles to its main course, as shown in the plan given in Fig. 11. The water in the river at this point hardly exceeded a foot in depth; but it spread over the greater portion of the space between the banks, necessitating the construction of a small foot bridge in

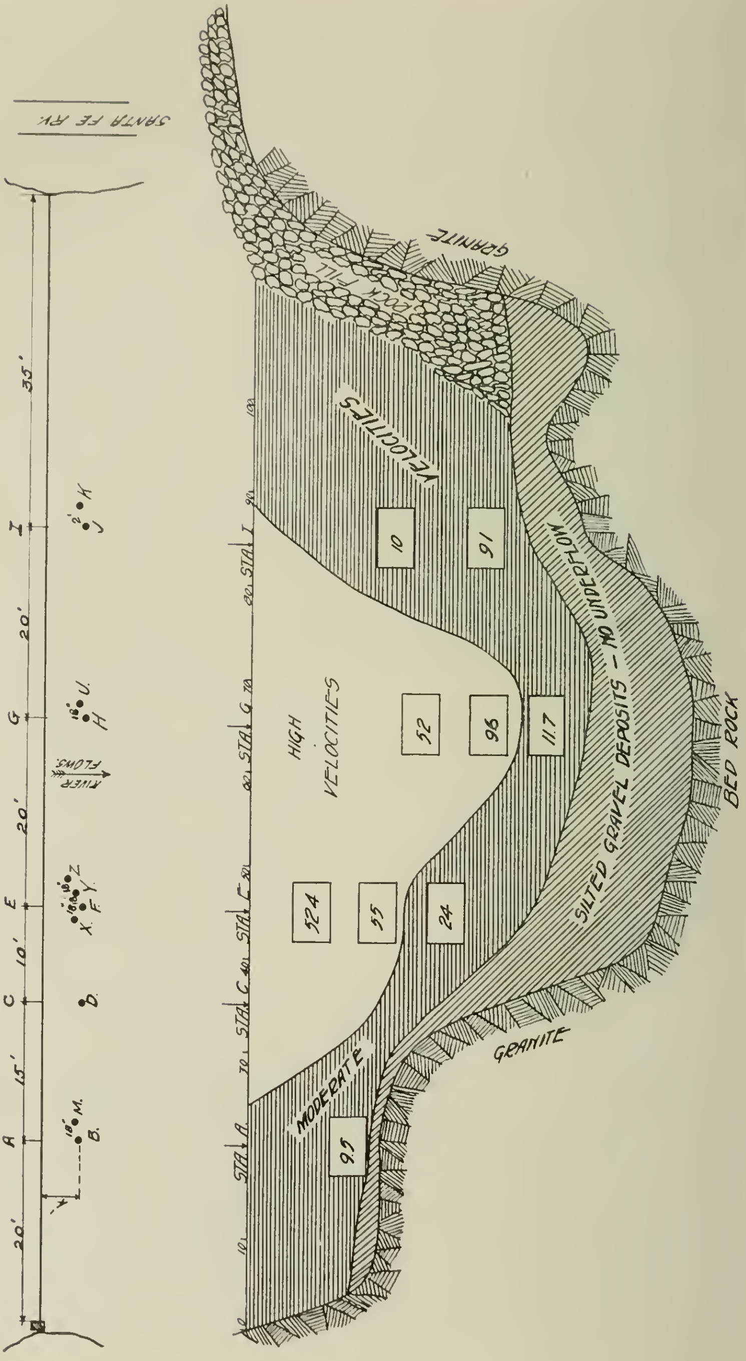

SANTA FE RY.
20'
15'
10'
20'
20'
35'
A
C
E
G
I
B.
M.
18'
D.
X.
F.
Y.
Z
H
U.
18'
J
K
2'
RIVER FLOWS
STA. A
STA. C
STA. E
STA. G
STA. I
MODERATE
HIGH VELOCITIES
VELOCITIES
ROCK FILL
GRANITE
GRANITE
SILTED GRAVEL DEPOSITS — NO UNDERFLOW
BED ROCK
9.5
524
55
24
52
96
11.7
10
16

Fig. 11.

order to facilitate the work. The double row of test wells, A, B, C, D, E, F, G, H, I, J, were driven across the river at the point as located on the plan shown. The gorge at this place is only 120 feet wide, and it was at first thought unnecessary to drive more than a single down-stream well for each measurement, as it was believed that the underflow must move through the gorge in a very direct course. It was determined, however, after first salting the up-stream wells, that the groundwaters must be moving through the gorge at this point at a slightly different direction from that of the surface waters, as absolutely no results could be obtained from the wells as first arranged. Accordingly, directional wells M, X, Y, Z, V, K, were driven, as also shown in this figure. In order to determine whether a variation in the direction was the cause of the failure to measure the underflow, some preliminary experiments were carried out at the position lettered E, test wells X and Y being driven eighteen inches from the well F. After these wells were put in place, the well E was salted. This test turned out to be unsatisfactory also, but a slight rise in the electric current in well Y was noticed, which encouraged us in the view that we had missed the direction of flow in our first test. We then concluded that the groundwater might be moving so rapidly as not to give time for the electrolyte to spread sufficiently, and hence was able to pass between two down-stream wells 18 inches apart. It was also possible that the direction of the flow was to the left of the new well Y. In order to provide for this contingency, the well X was pulled and redriven in the position indicated by the letter Z, 18 inches from Y.

If it were true that the motion of the groundwater of the underflow might be so great that the electrolyte used in well E would not have time to spread sufficiently so as to be certain of coming in contact with one of two down-stream wells 8 inches apart, it would be necessary to modify the method of salting E so as to cause, if possible, a wider path to be traversed by the electrolyte. This was finally accomplished by introducing into the well E along with the dry sal ammoniac, about 10 per cent caustic soda, or common soda lye. This, of course, brought about a reaction between the two salts in solution, ammonia gas being liberated. It was believed that the liberation of the gas would cause the mixed chemicals to spread more rapidly in the groundwaters. This later seemed to be the case, for carrying out the experiment in this way, it was found that the electrolyte reached well Y, where it showed itself very strongly, and just grazed well F. The electrode curve for well Y is shown in Fig. 12, which indicated a velocity of groundwaters of about 52.4 ft. for 24 hours. This velocity was several times greater than any I had previously determined, which accounted for the difficulties we encountered in interpreting our first failure and in getting the direction of flow. After this experience all of the upstream wells were salted with the same mixture of sal ammoniac and caustic soda and no further difficulties were experienced in getting the velocity and direction of flow. At the various stations A, E, G, I, determinations of velocity were made at various depths as is shown by numbers enclosed in rectangular lines at appropriate points in the cross-section, Fig. 11. The pipe casing of well D was found to be broken below the ground and station C was on that account not used.

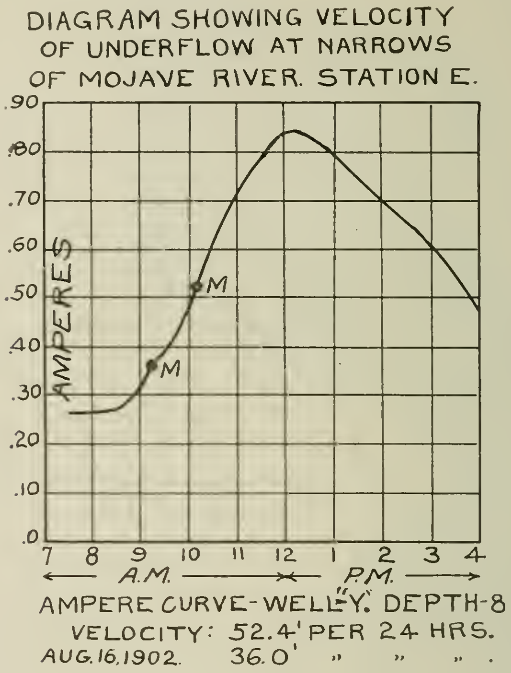


Fig. 12.

Another determination, that of Well K. of this same series is shown in Fig. 13.

At depths below the surface not exceeding 25 or 30 ft. the gravel of the gorge is completely silted with fine material deposited by the river, and is, of course, impervious. At stations E, G, and I, after the well points were driven a few feet below the point at which the deepest measurements were made the points were completely imbedded in the silted gravel and no water could be drawn from the wells with an ordinary pump. It was therefore very plain that the underflow of the gorge was confined to a depth not exceeding about 30 feet. All of the velocities determined in the clear gravel of the gorge ran very high, three of them exceeding a velocity of fifty feet for 24 hours. Taking Schuyler's figures for the area of the cross-section of the gorge, 4,160 square feet, and assuming a mean

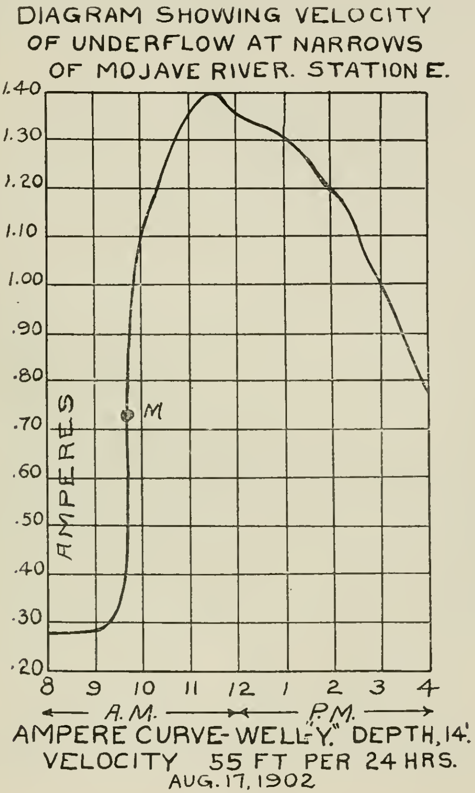


Fig 12 A

velocity of groundwater in the entire section of 50 feet for 24 hours, and estimating the porosity of the gravel at 33 1/3 per cent, the total underflow in the gorge will be found to be less than one second-foot. This must be understood to be a maximum estimate. The underflow probably does not exceed 300,000 gallons for 24 hours. The gradient of the water plane at and above the gorge is almost exactly 20 feet to the mile.

DESCRIPTION OF UNDERFLOW METER, USED IN MEASURING THE VELOCITY AND DIRECTION OF MOVEMENT OF UNDERGROUND WATERS.

The apparatus used is of two types: (1) direct reading, or hand apparatus, requiring the personal presence of the operator every hour for reading the instruments, and (2) recording apparatus which requires attention but once in a day. The arrangement of the test wells and manner of wiring the wells is essentially the same in both cases.

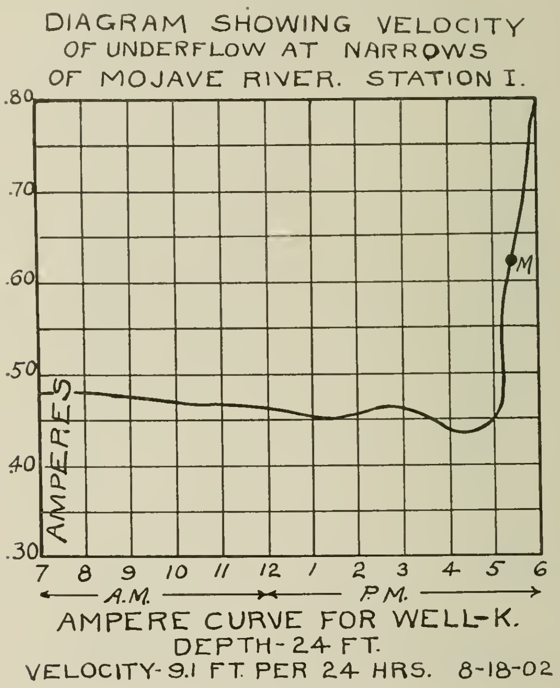


Fig. 13.

The test wells suitable for use with the underflow meter in determining the velocity of groundwaters may be common 1½-inch or 2-inch drive wells, if the soil bearing material is easily penetrated and if the depths desired to be reached do not exceed 50 to 75 ft. For greater depths and more difficult material, wells of heavier construction should be used. The 1½-in. drive wells are much preferable to the 1¼-in. size because of the fact that 1½-in. pipe is lap-welded, while the 1¼-in. pipe is butt-welded, and less capable of standing severe pounding. The drive point used with the well may be 1½-in. standard brass jacket well points 42 in. to 48 in. long, with No. 60 brass gauze strainer. The well points should be threaded with 1½-in. of standard thread, somewhat more than is usually found on the trade goods. The pipe should be full weight, strictly wrought iron standard pipe, cut in lengths of 6 or 7 feet, and threaded 1½ in. at each end. The couplings should be wrought iron hydraulic recessed couplings, and the thread upon the pipe should be cut in such a way that when properly screwed up the ends of the pipe will abut. The recessed couplings protect the pipe at its weakest point, while an ordinary coupling will leave exposed a thread or two of the pipe, so that severe driving is liable to swell and ultimately rupture the pipe just above the coupling.

The driving head should be made of rolled steel shafting and should be about 4 inches long, carrying 1½ ins. of standard thread and an air hole to permit the free esacpe of air from the well while the driving is in progress. A driving ram for putting down the drive well should be about 5½ ft. long by 5½ ins. in diameter, made of heavy oak or other tough wood, with iron bands shrunk on the ends, and bearing two handles of hard wood at each end, in order to facilitate the handling of the ram by two men. It is convenient to have these handles placed one about one foot from one end, and the other about two feet from the other end. By reversing the ram the handlers are brought in a more convenient position for driving as the well goes down. If the test wells are to be sunk to a depth exceeding that to which drive points can be readily driven, open end 2-in. wells should be used. These wells should be of full weight, strictly wrought iron 2-in. pipe with long threads and recessed hydraulic coupling as described above. The pipes can be put down without a strainer, in which case a 1¼-in. well point with turned coupling may be inserted through a drive shoe at the bottom of the casing after the well is driven into place, or an open end brass-jacket well point, 48 ins. long, may be put down with the well. The casing should be driven into place with a cast iron ram varying in weight from 150 to 250 lbs., simultaneously hydraulicking a passage for the pipe with a water jet in ¾-in. wash pipe. There are many hand-rigs on the market suitable for this work, or a rig can be readily constructed by any good mechanic. A suitable pump for the hydraulic jet is a double-acting horizontal force pump with a 4-in. by 4½-in. cylinder. If the material in which the well is to be drilled is not too hard nor too full of boulders, the writer recommends that an open end well point be put down with the casing. This is apt to cause some difficulty in the proper working of the hydraulic jet, through the screen of the well point. This difficulty can be obviated and a more powerful wash secured by admitting a considerable quantity of air along with the water at the suction end of the force pump. The exact amount of air to be admitted can be readily determined with a little experience. The effect of the air entering the well under high pressure is to form a powerful air lift which will throw out from the top of the well casing the water and gravel with great force. It has been the writer's experience that the best hydraulic samples are obtained with the combination hydraulic pneumatic jet. With the hydraulic jet alone, the coarser particles have a tendency to remain at the bottom of the well.

After a test is completed, the well casing can readily be pulled by a Number 2 cast iron pipe puller, and two five-ton railroad jacks. Sets of dies for the pipe puller to fit both 1½-in. and 2-in. pipe can be obtained at small cost. In Fig. 1 is shown the operation of the pipe puller and railroad jacks. The test wells are driven in groups as shown in Fig. 2, each group of wells constituting a single station for the measurement of the direction and rate of flow of the groundwater. In case the wells are not driven deeper than twenty-five feet, an "upstream" or "salt well," A, is located, and three other wells B, C, and D, are driven at a distance of four feet from A, the distance between B and C and C and D being about two feet. The well C is located so that the line from A to C will coincide with the probable direction of the expected groundwater movement. This direction should coincide, of course, with the local slope of the water plane, and if this is not accurately known, it should be determined

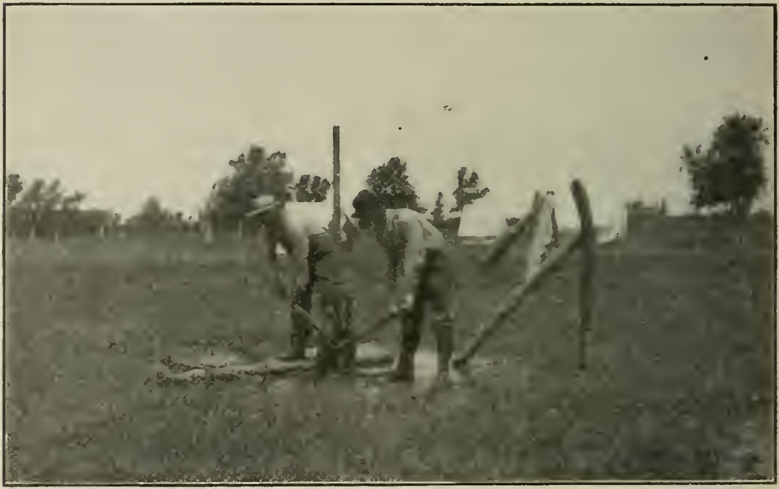


Fig. 1.

by means of leveling. For deeper work the wells should be located farther apart, as shown in the right portion of Fig. 2. For depths exceeding seventy-five feet, a radius of eight or nine feet and chords of four feet should be used, the general requirement being that the wells should be as close together as possible so as to cut down to a minimum the time required for a single measurement, but not so close that important errors are liable to be introduced by the inability to drive the wells perfectly straight and plumb. On this account the deeper the wells, the further apart they should be placed. The angles B A C and C A D should not exceed 30 degrees.

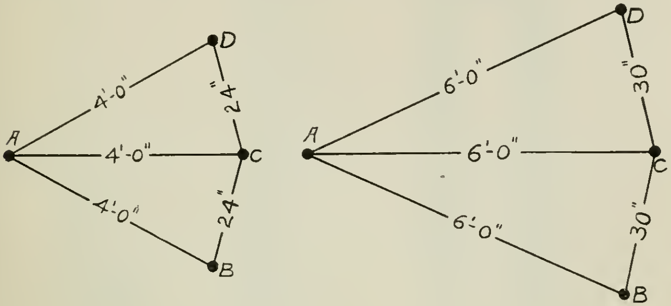


Fig. 2.

Electrical connection is made with the casing of each test well by means of a drilled coupling carrying a binding post. Each of the downstream wells B, C, D, contains within the well point, or screen section, an electrode consisting of a nickeled brass rod ⅜ in. in diameter and 4 ft. long, insulated from the casing by wooden spools. An electrode is shown in Fig. 3. This electrode communicates with the surface by means of a rubber covered copper wire. Fig. 4 illustrates the arrangement of electric circuits between the upstream well and one of the down-stream wells. Each of the downstream wells is connected to the up-stream well in the manner shown in this figure.

A photograph of the direct reading underflow-meter is shown in Fig. 5. Six standard dry cells are contained in the bottom of the box, their poles connected to the six switches shown at the rear of the case. By means of these switches, any number of the six cells may be thrown into the circuit in series. One side of the circuit terminates in eight press keys, shown at the left end of the box. The other side of the circuit passes through an ammeter shown in the center of the box, to two three-way switches at right end of the box. Four of the binding posts at the left end of the box are connected respectively to the casing of well A, and to the three elec-

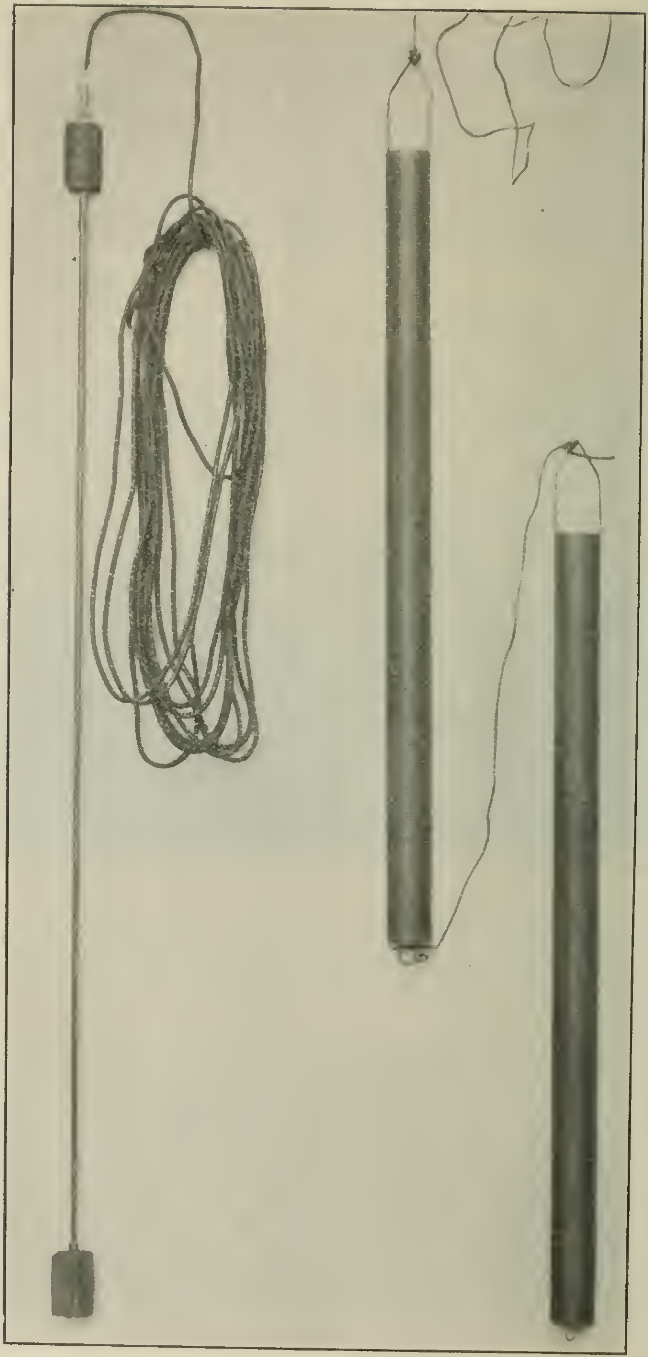


Fig. 3. Electrode and Wire Perforated Buckets for Salting a Well.

trodes of wells B, C, and D, in the order named. The binding posts at the right end of the box are connected to the casings of wells B, C, and D. There are enough binding posts so that two different groups of wells can be connected to the same instrument. When the three-way switch occupies the position shown in the illustration,

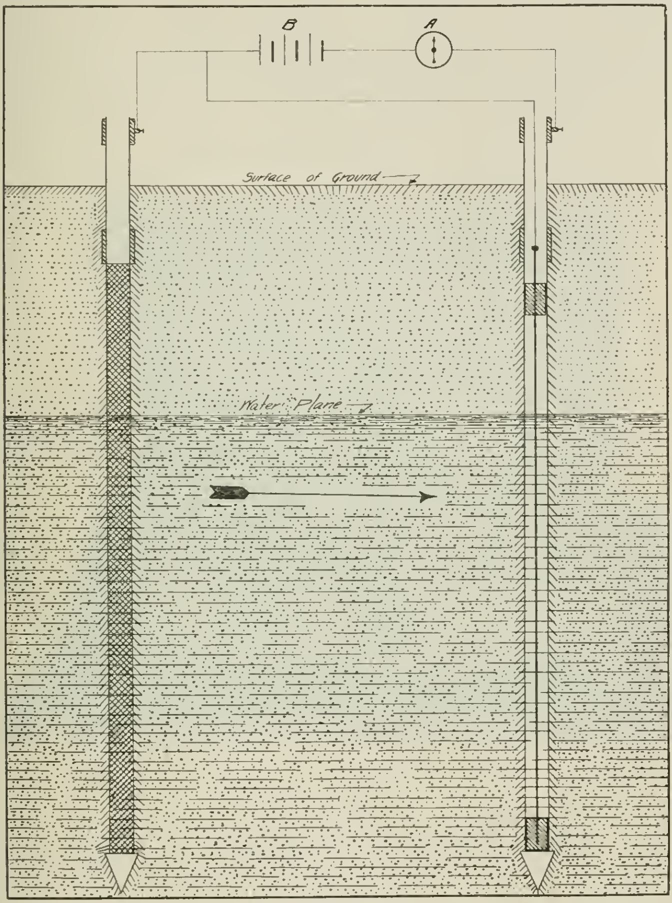


Fig. 4.

on pressing the first key at left end of the box, the ammeter will show the amount of current passing between casing of well A and casing of well B. When the next key is pressed the ammeter will indicate the current between the casing of well B and the electrode contained within it. In one instance the current is conducted between the two well casings by means of the groundwater in the soil; in the second case the electric circuit is completed by means of the water within well B. By putting the three-way switch in second position and pressing the first and third keys in turn, similar readings can be had for current between casings A and C, and between casing C and its internal electrode. Similarly with the switch in the third position, readings are obtained by pressing the first and fourth keys.

The principles involved in the working of the apparatus are quite simple. The up-stream well A is charged with a strong electrolyte, such as sal ammoniac, which passes down stream with the moving underground water, rendering it a good electrolytic conductor of electricity. If the groundwater moves in the direction of one of the lower wells, B, C, D, etc., the electric current between A and B, A and C, or A and D will gradually rise, mounting rapidly when the electrolyte begins to touch one of the lower wells. When the electrolyte finally reaches and enters inside of one of the wells B, C, D, it forms a short circuit between the casing of the well and the internal electrode, causing an abrupt rise in the electric current. The result can be easily understood by consulting Fig. 6, in which the electric current as observed in an actual field test is depicted graphically.

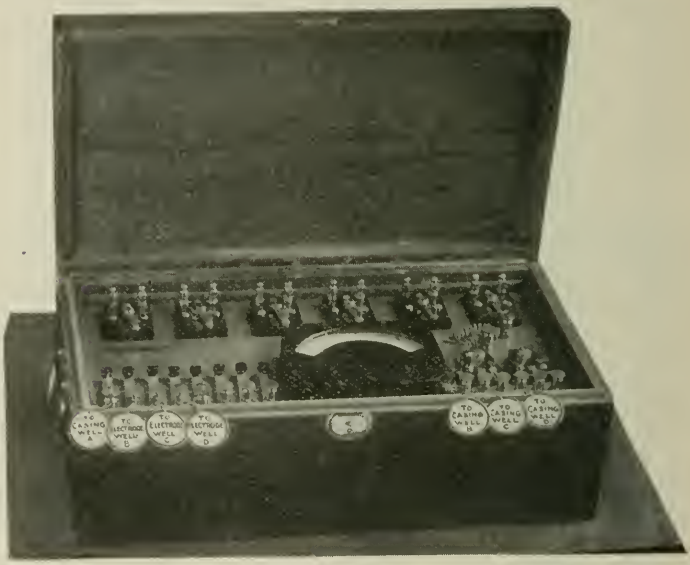


Fig. 5.

The time which elapses from the charging of the well A to the arrival of the electrolyte at the lower well gives the time necessary for the groundwater to cover the distance between these two wells. Hence, if the distance between the wells be divided by this elapsed time, the result will be the velocity of the groundwater. The electrolyte does not appear at one of the down-stream wells with very great abruptness, but its appearance there is somewhat gradual, as shown in the curves in Figs. 6 and 7. The time required for the electrolyte to reach its maximum strength in one of the down-stream wells (and hence, for the current to reach its maximum value), may vary from a few minutes, in a case of high velocity of the groundwater to several hours, in a case of low velocity. The writer formerly supposed that the gradual appearance of the electrolyte at the down-stream well was largely due to the diffusion of the dissolved salt, but it is now known that diffusion plays but a small part in the result. The principal cause of the phenomena is

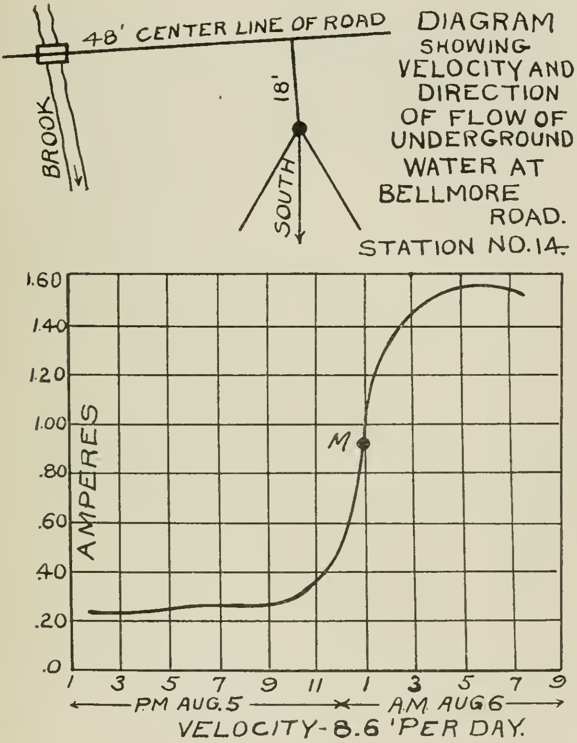


Fig. 6.

due to the fact that the central thread of water in each capillary pore of the soil moves faster than the water at the walls of the capillary pore, just as the water near the central line of a river channel usually flows faster than the water near the banks. For this reason, if the water of a river suddenly be made muddy at a certain upstream point, the muddiness of the water will appear somewhat gradually at a down-stream point, being first brought down by the rapidly moving water in the center of the channel, and later on by the more slowly moving water near the banks. The effect of the analogous gradual rise in the electrolyte in the down-stream well, requires us to select the "point of inflection" of the curve of electric current, as the proper point to determine the true time at which the arrival of the electrolyte should be counted. This point is designated by the letter M in the Figs. 6 and 7.

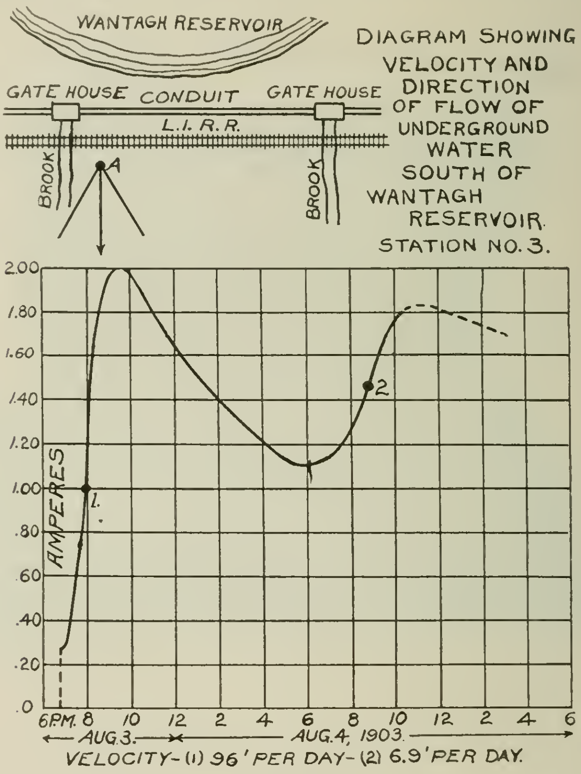


Fig. 7.

Owing to the repeated branching and subdivision of the capillary pores around the grains of the sand or gravel, the stream of electrolyte issuing from the well will gradually broaden as it passes downstream. The actual width of this charged water varies somewhat with the velocity of the groundwater, but in no case is the rate of divergence very great. The manner in which the electrolyte spreads, has been carefully investigated. The width of the stream is about 3 ft. at a distance of 4 ft. downstream from the "salt" well, when the groundwater velocity is about 12 ft. in 24 hours. The electrolyte spreads somewhat less for higher velocities. It is possible to dispense with the circuit between the casing of well A to the casing of each of the other wells, as the short circuit between the well and electrode forms the best possible indication of the arrival of the electrolyte at the down-stream well. For cases in which the velocity of groundwater is high the circuit to well A is practically of no value, but for slow motions this circuit shows a rising current before the arrival of the electrolyte at the lower well, often giving indications of much value to the observer.

The method can be used quite successfully even though nothing but common pipe be used for the wells. In this case, however, the absence of screen or perforations in the wells renders the internal electrodes useless, and one must depend upon the circuit from well casing of the up-stream well to well casing of down-stream well.

Granulated sal ammoniac is used to dose the well A. A single charge may vary from four to ten pounds. If common pipe without points or screen is used for the wells, so that internal electrodes must be dispensed with, doses of about two pounds each should be repeated about every hour. The dry salt should not be poured directly into the well, but should be lowered in perforated buckets, as shown in the illustration, Fig. 3. These buckets are 1¾ in. diameter and 30 ins. long, and hold about two pounds of the salt. Two of these buckets may be tied one above the other for the initial charge, and followed by two more in ten or twenty minutes.

If the wells are not too deep, the sal ammoniac may be introduced into the well in the form of a solution. A common bucket full of saturated solution is sufficient. There is an uncertainty in introducing the sal ammoniac in solution in deep wells, as the time required for the solution to sink to the bottom of the well may be considerable.

The direct reading ammeter used in the work has two scales, one reading from 0 to 1.5 amperes and the other from 0 to 5 amperes. With a given number of cells, the amount of current between the up-stream and a down-stream well will depend, of course, upon several factors, such as the depth and distance apart of the wells, but more especially upon the amount of dissolved mineral matter in the groundwater. The initial strength of the electric current can be readily adjusted, however, after the wells have been connected with the instruments, by turning on or off some of the battery cells by means of the switches at the rear of the box. It is a good plan to use enough cells so that the initial current lies between one-tenth and two-tenths of an ampere.

In the second form of underflow meter, a self-recording instrument is used in place of the direct reading ammeter, thus doing away with the tedious work of taking the frequent observations day and night, which are required when direct reading instruments are used. The arrangement of the apparatus is not materially different from that described above. In the place of the direct reading ammeter, a special recording ammeter is used of range 0 to 2 amperes. It has been found practicable, although a matter of some difficulty, to construct an instrument of this low range sufficiently portable for field use and not too delicate for the purpose for which it is intended. The ammeter has a resistance of about 1.6 ohms, and is provided with an oil dash pot to dampen the swing of the arm carrying the recording pen. The instruments were manufactured

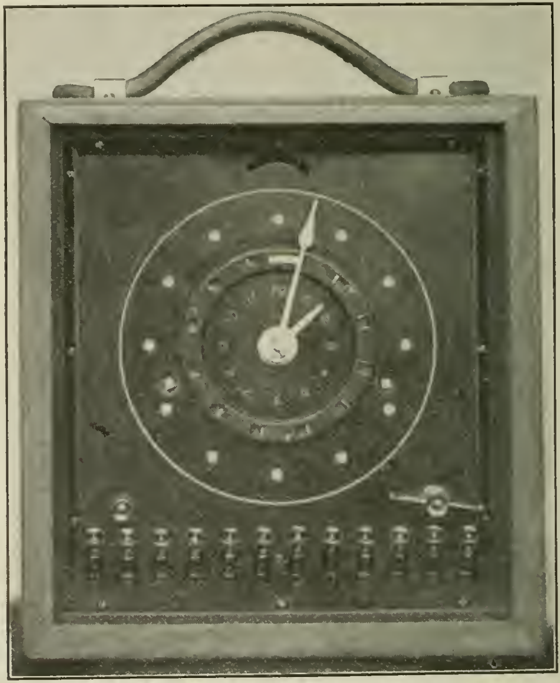


Fig. 8.

by the Bristol Company. They have gone through hard usage in the field without serious breakage or mishap. The portability of the instruments will be materially increased by changes in design which are now being made.

The methods of wiring the wells when the recording instruments are used is slightly changed. In this case one side of the battery circuit is connected to casing of well A and to all of the electrodes of wells B, C, and D. The other side of the battery is run through the recording ammeter to a commutator clock, which once every hour makes a contact and completes the circuit, one after the other, to a series of binding posts. One of these binding posts is connected to the casing of well B, one to the casing of well C, and one to the casing of well D. The time of contact is ten seconds, which gives an abundance of time for the pen to reach its proper position and to properly ink its record.

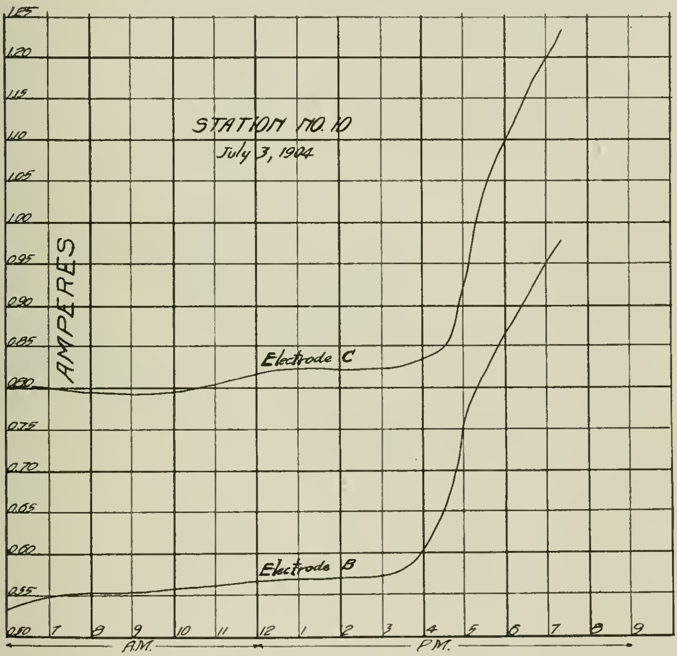


Fig. 9. Arkansas Valley, Kan.

In Fig. 8 is shown a commutator clock made for this purpose by the instrument maker of the College of Engineering, University of Wisconsin. The clock movement is a standard of fair grade, costing less than five dollars. It can readily be taken from the case for cleaning or oiling, and quickly replaced. A good movement with powerful springs is best for this purpose.

It will be seen from the method of wiring the wells that the record will show the sum of the current between well A and well B added to the current between the casing of well B and its electrode. The removal of the connection to well A would permit the record to show the current between the casing of a down-stream well and its electrode, but the connection to the up-stream well involves no additional trouble and, occasionally, its indications are of much service, especially if the velocities are low. All of the instruments above mentioned can be placed in a common box, 16 in. by 22 in. by 36 in., covered with tar paper and locked up.

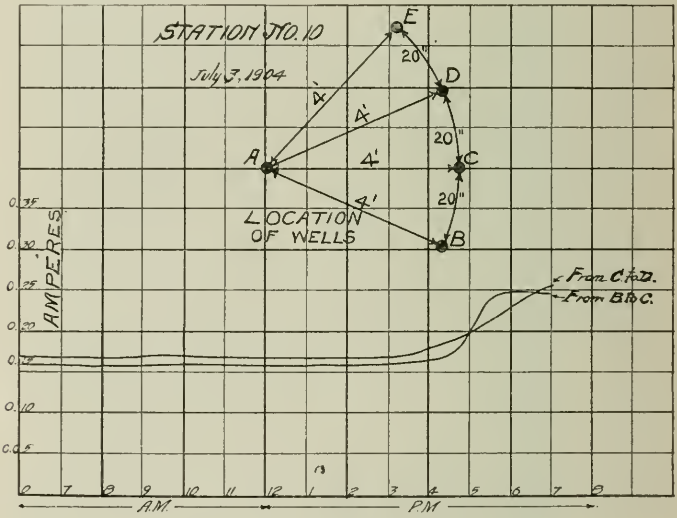
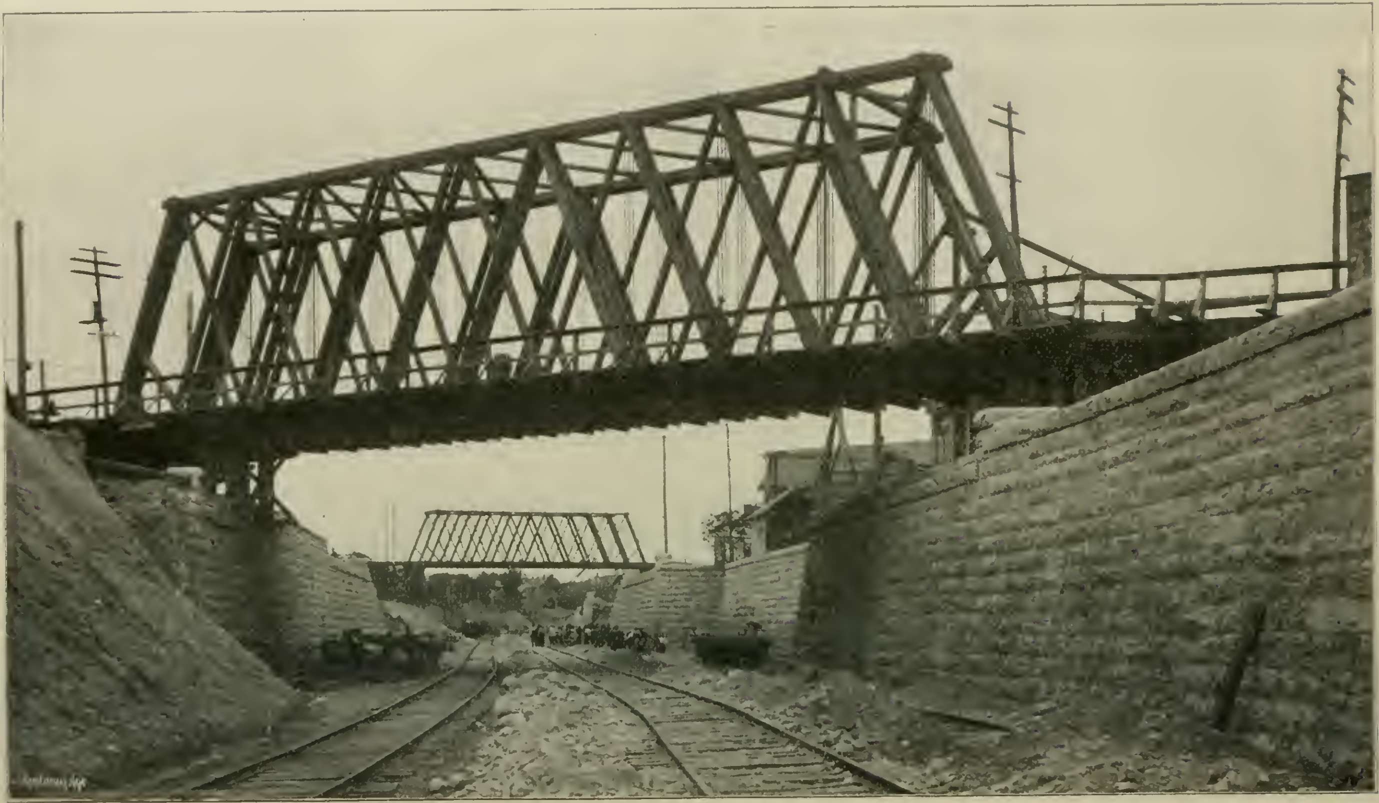


Fig. 10. Arkansas Valley, Kan.

The contacts on the commutator clock are arranged about five minutes apart, so that the record made for the wells will appear on the chart as a group of lines, one for each down-stream well, of length corresponding to the strength of the current. The increasing current corresponding to one of the wells will finally be indicated by the lengthening of the record lines for that well. The record charts are printed in light green ink and red ink is used in the recording pen, so that record lines can be distinguished when superimposed upon the lines of the chart. A special chart has been designed for this work, and is furnished by the Bristol Company as chart 458.

The recording instruments in use have given perfect satisfaction and the method is a great improvement in accuracy and convenience over the direct reading method. The highest as well as the lowest groundwater velocities yet found have been successfully measured by the recording instruments. By using one or two additional dry cells the instrument is quite as sensitive as the direct reading type. In using the recording instrument but a single charge of salt need be placed in the up-stream well. If the wells are deep it is important to use enough salt or solution to insure that the salt reaches as deep as the screen of the well point immediately after the solution is poured into the well. A gallon of solution will fill about 6 ft. of full weight, wrought iron pipe, so that ten gallons of solution should be used if the well is 60 ft. deep. If the proper amount of solution be not used it will take an appreciable time for the solution to reach the bottom of the well by convection currents and the results will be vitiated to that extent. As before stated, it is preferable to introduce into the well granulated sal ammoniac contained in a suitable bucket, in case the depth of the well renders the use of a solution uncertain.

Before salting the up-stream well of any set of test wells, the electric circuit should be closed between each adjacent pair of down-stream wells and the current measured with the direct reading ammeter and recorded in the note book. An occasional reading of these same circuits will obviate the electrolyte passing between two of the down-stream wells without the knowledge of the observer. This is nicely shown by the results obtained with the set of wells shown in Figs. 9 and 10. At the location of this station the direction of the flow was at first not correctly estimated on account of its nearness to a river whose height was fluctuating. For that reason the down-stream wells were redriven at distances of but 20 inches from each other. The diagram gives the ampere curves for wells B and C, both of which were reached by the electrolyte, and also the curves of current between wells B and C and wells C and D. The actual direction of flow can be seen from these curves to lie between B and C, and probably nearer B than C, since the curve for B rises somewhat earlier and the percentage increases in current is greater. The same fact is shown by the curves representing the current between B and C and between C and D. The main stream of electrolyte must have passed between B and C, as is shown by the more abrupt and earlier rise of the current between B and C as compared to that between C and D.



TRACK DEPRESSION OF C. & N. W. RY. IN MILWAUKEE—COURTESY OF "RAILWAY AGE."

THE EXCURSION TO MILWAUKEE, WIS., AUG. 26, 1904.

On the above date the Western Society of Engineers made an excursion to Milwaukee to inspect the track depression of the Chicago & Northwestern Railroad. This railroad company provided a special train for the trip. The party, consisting of about 150 persons, including ladies, left Chicago at 9:15 a. m. and arrived at Milwaukee about 11:30 a. m. The route taken was over the Skokie cut-off recently completed, which joins the main track at Lake Bluff, there being no stop made between Mayfair and that point. This allows fast trains to avoid the traffic between Chicago and the smaller towns north along the lake.

Arriving at Milwaukee, a box lunch was served on the train, after which the party was taken to the Northwestern end of the track depression near to Whitefish Bay, where some of the ladies spent the afternoon. The majority of the gentlemen of the party boarded a construction train in order to have a more satisfactory view and study of the work done at the track depression. Mr. E. C. Carter, chief engineer, and Mr. Wm. H. Finley, principal assistant engineer, of the Chicago & Northwestern Railway, conducted the party on their tour of inspection. Mr. C. I. Poetsch, city engineer, of Milwaukee, and Mr. B. W. Perrigo, assistant city engineer, were also of the party. The construction of the track depression involved the excavation of two miles of road to an average depth of about 18 feet, the maximum depth being 19½ feet. Actual track depression begins about a mile north of the main passenger station in Milwaukee. In order to provide room for a three-track system, the construction of a sea-wall was necessary along part of the way, as a protection to the embankment against the encroachment of Lake Michigan. This wall is of concrete, about 2,450 feet long. The width of the depression is 63 feet, the maximum gradient is 0.3 of one per cent, and the elevations are from 38 feet to 45 feet above the city datum. The construction of this work necessitated the lowering of sewers and watermains about 26 feet, which brings their present location about 5 feet below the top of the sub-grade. The rubble stone for this masonry was supplied from a quarry at Duck Creek, owned by the railway company. This quarry furnishes rock of exceptional quality. The illustration shows a view of two of the bridges for the overhead street crossings, and the massive character of the masonry retaining walls.

After viewing the track depression, a short visit was made at the works of the National Electric Co. From there the party went on to inspect the pumping station of the river flushing works, and the new breakwater, which consists of a concrete block superstructure on the substructure of the old crib breakwater. The concrete pier was also visited by some of the party.

The special train then carried the visitors to West Allis, to the new "Model" works of the Allis-Chalmers Co. Booklets containing a map of the works were distributed, in which the route through the several shops was laid down in red ink. The works are a model from many points of view, and considerable interest was manifested by many of the party in the various departments. A group photograph of the visitors was made on the trip through the shops.

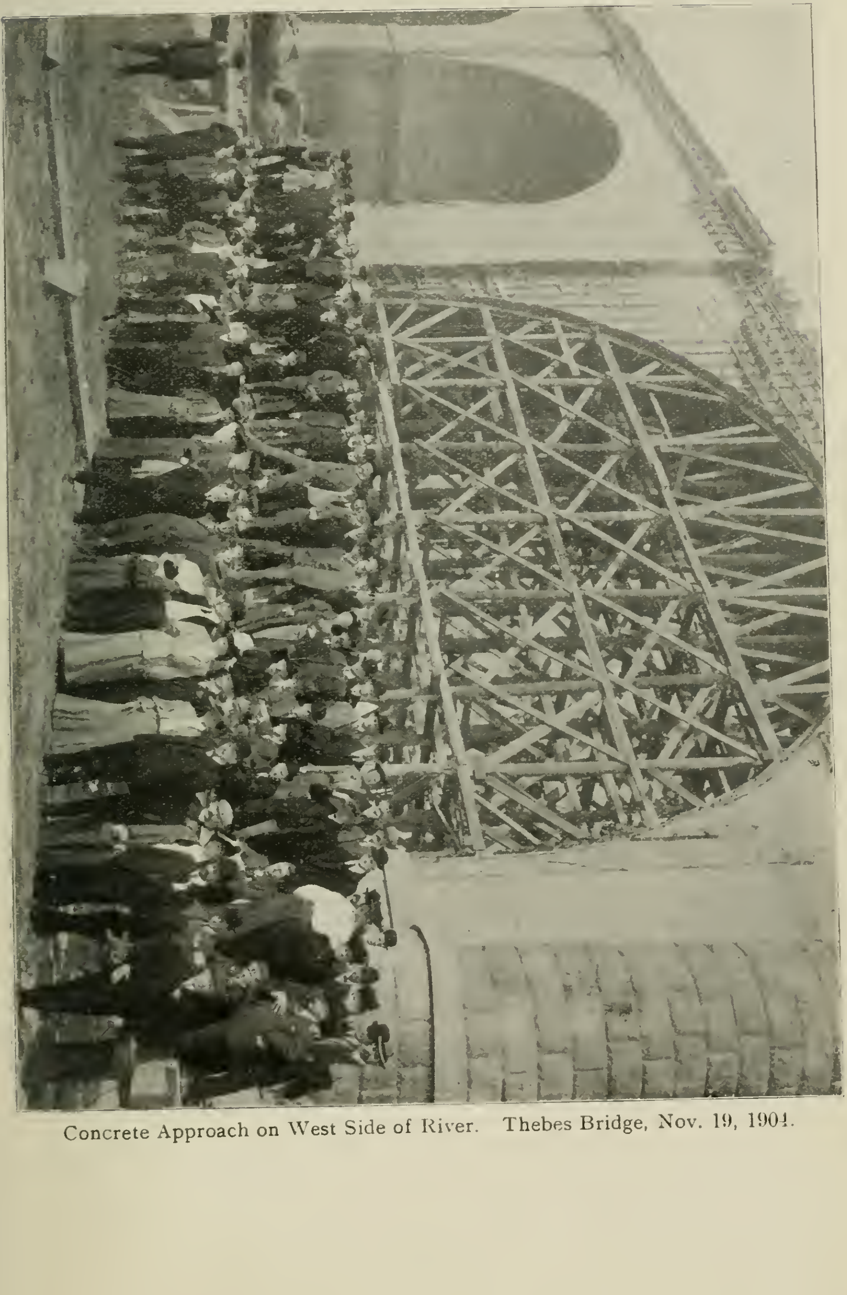
After leaving the Allis-Chalmers works the train brought the party back to the city where an opportunity was afforded to view the new plant of the Milwaukee Coke & Gas Co., the principal feature of which is the manufacture of coke on a large scale in the Semet-Solvay Co.'s by-product ovens. The train then conducted the party to Whitefish Bay, where supper was served in the hotel overlooking the lake. The party started on the return trip at 7 p. m., leaving Milwaukee at 7:35 p. m., and arriving in Chicago at 9:45 p. m., and all declared they had a very enjoyable trip.

A. L.

EXCURSION TO ST. LOUIS AND THEBES, ILL.

On November 17th, 1904, the society made a special trip to St. Louis and to Thebes, to view the great International Exhibition and to see the progress of construction upon the great cantilever bridge over the Mississippi River.

A party of about ninety members and guests (including several ladies) left Chicago at 9:27 p. m., Thursday, Nov. 17th, in three special Pullman cars attached to the regular train of the Illinois Central Railway. The train reached St. Louis about 8:30 a. m. Nov. 18th, and breakfast was served at the Union Station. Special street cars, provided through the courtesy of the Engineers' Club of St. Louis, then conveyed the party to the Exhibition, and the day was left free for members to follow their own preferences. In the evening there was a dinner at the restaurant of the Tyrolean Alps, tendered by the Engineer's Club of St. Louis, and later the party returned to the station to their cars, which were attached to the night train of the St. Louis Southwestern Railway. Other cars containing members of the St. Louis Engineers' Club were also added to the train. These were detached at Thebes early on the morning of Nov. 19th. A hearty breakfast was served in the dining room of the construction camp of the Kelly & Atkinson Con-



Concrete Approach on West Side of River. Thebes Bridge, Nov. 19, 1904.

struction Co., and a train of flat cars was then provided to take the party over the connecting line and up to the bridge, being run out to the end of the completed iron work.

Returning to the river, a steamer and barge ferried the party across to the Missouri side, where the approaches and steel work were inspected, and another flat car ride was taken. The ferry brought the party back to Thebes in time for luncheon at the camp, and the cars were then attached to the 1:00 p. m. train of the St. Louis, Iron Mountain & Southern Railway for the return to St. Louis.

By courtesy of the Terminal Railroad Association of St. Louis the cars were detached and run as a special to the Wabash Railway Terminal Station at the Exhibition, giving an opportunity for another visit to the great "World's Fair."

The cars were placed on a siding for the night, and Sunday morning, Nov. 20th, were taken to the Union Station and attached to the 9:20 a. m. train of the Chicago & Eastern Illinois Railway, giving a daylight ride over the new Chicago-St. Louis line of that company. The train reached Chicago about 6:00 p. m., ending a very enjoyable trip.

The committee in charge of the trip was composed of Messrs. J. J. Reynolds, T. W. Snow, Andrews Allen, and Ralph Modjeska, and at a meeting of the society on Dec. 7th, a vote of thanks was passed to the committee and to the railway companies and others, who had extended courtesies and helped to make the entertainment pleasant and successful.

SUBJECTS FOR PAPERS, SUGGESTED BY MEMBERS OF THE SOCIETY.

Some time ago a circular was sent out to all the members of the Society, in regard to securing papers. This circular is as follows:

DEAR SIR: October 25, 1904.

The Publication Committee desires to secure technical papers of interest to the Society and the readers of the "JOURNAL." It believes that better results may be obtained by the co-operation of the members, and respectfully requests that each send in suggestions of topics for papers to be presented and discussed.

Will *you* kindly use the attached postal card for this purpose, and will you please give the matter your immediate attention?

Replies were received from over 80 members, or about 10 per cent of the membership, with suggestions for about 176 subjects to be discussed before the Society. The Publication Committee considers it desirable to have this list printed in the JOURNAL, that it may reach the members of the Society as well as the readers of the JOURNAL. The Committee hopes this list will be of interest to many and may induce some to present papers on some of these subjects. Every reader is requested to carefully examine the list and to bear in mind that offers of papers on any of the subjects will be highly appreciated by the Society. Very respectfully,

THE PUBLICATION COMMITTEE,
J. H. Warder, Secretary.

Aeronautical exhibits and experiments at St. Louis.
Engineering as represented at the St. Louis Exposition.
Advice to engineers in general; Men of 30 to 40 years of age.
Should engineers interest themselves in sociology?
The importance of our engineering profession in the evolution of the human race.
The engineer's common business training, versus erratic technical attainments.
Smoker, with several informal talks on profitable vacations taken by various members.
A symposium on the relative value of cost of estimation from published data, vs. experienced judgment; in civil engineering and general contracting.
The utter helplessness of civil engineers and draftsmen in the matter of employment. The inability of civil engineers to secure justice if dismissed.
Popular lecture on Panama, by Mr. Karner for some "Ladies' Night."
Panama canal.
River and harbor improvements.
Marine docks for the Chicago Drainage Canal and the Calumet River.
Harbor necessities of Chicago.
Subway for Chicago's passenger and freight traffic.
Underground railway system for Chicago.
Comparative cost of the New York subway and similar work in Chicago.
Chicago tunnel system.
The Illinois Tunnel Co's work under Chicago. Its present and its future scope.
The saving in operating expenses, due to grade reductions.

The value of organization in engineering work.
Further papers in powdered fuel and with special reference to malleable annealing.
Absolute fireproof construction.
Fireproof grain elevators.
Arrangements for removing dust from foundry tumbling barrels and cleaning the air used in the process.
The arranging and publication of a standard classification of engineering "Notes," "Catalogues," etc.
How to inculcate habits of observation in students of engineering.
The new Hawthorne shop of the Western Electric Co. (Two requests.)
The testing of materials.
Steel casting processes and improvement in steel castings.
Paper manufacturing.
Water wheels and testing the same.
The volumetric and efficiency tests of Air Compressors.
Compressed air—The economic installation of plants.
Water power construction works.
Modern practice in street paving.
Asphalt.
The phenomena of high speed shafts.
Stresses and strains due to very high rotative speeds.
Physical chemistry as related to thermodynamics and molecular mechanics.
The drying of glutinous materials.
Utilization of waste heat from furnaces and kilns.
Performance of centrifugal and other rotary pumps.
Comparison of brick and steel smoke stacks.
Combined steam and water power as an electric power producer.
Modern methods of handling and conveying materials; ore, coal, dirt.
Method of filling submerged area.
Boulevard connection from north to south sides.
The best and most economical construction for permanent shore protection or sea wall for Lincoln Park (north) and Grant Park (south.)
How can we improve our engineering structures with special reference to their looks?
Esthetics in bridge design.
Advice to structural engineers and draftsmen, ages between 25 and 40.
Structural steel work.
Advice to railroad engineers.
The prevention of railway wrecks.
The relation of freight and passenger traffic to population.
Economics of railway operation.
Proper sphere of work for a state railroad commission.
Ventilation of railway tunnels under existing conditions and advisability of electric locomotives for use in such tunnels.
Interurban electric railways,—on determining the practicability from a commercial standpoint—applying to the middle west.
Stadia surveys for railroad locations.
Economics of transportation, etc.
Recent methods of carrying out grade reductions.
Economic principles involved in revision of railroad lines.
Topography and topographical surveying.
Railroading, especially signaling.
Railroad signal engineering.
Rail Fastenings; joints, spikes, lag-screws, etc.
Kinks in frog, switch and crossing work.
American vs. European track practice.
The change from steam to electricity, as a motive power of trunk line railroads, water power to be used where possible.
The saving in operating expenses due to grade reduction.
Construction of railroad embankments.
Determining the dimensions of waterway areas for railway bridges and culvert openings.

Steel vs. cypress tanks for water storage.
Methods, devices, etc., for test borings for bridge, building, and other foundations.
Proportioning of abutments and retaining walls.
Waterproofing for masonry and concrete arches and retaining walls.
Waterproofing for bridges, concrete, stone, masonry, etc.
Waterproof floors for railway viaducts.
Painting of steel structures.
Cheapest fireproof permanent substitute for long low pile railroad bridges for heavy equipment where wide shallow water way is necessary.
Organization of a railway bridge department.
Swing bridges, continuous and non-continuous.
Erection of bridge work of various classes.
The Boone Viaduct. C. & N.-W. Ry.
The Plattsmouth Bridge. C., B. & Q. R. R.
A uniform and universal specification for the fabrication of structural steel in bridges and buildings.
The relative value of various types of bridges for spans over 50 ft.
Solid floor construction for railway bridges.
Design of lift and bascule bridges.
Comparative merits of draw and lift bridges.
The South-Side elevated railroad construction.
Design of office buildings.
Shop or mill buildings recently erected and the way they are heated and ventilated. Buildings where the designs or way of construction is out of the ordinary and which would be of interest to structural engineers.
Design of steel frame office buildings.
Caisson foundation in Chicago.
High building construction, foundations, etc.
Deep foundations and tall buildings in Chicago.
The Jackson channel-bar, "United States" and other steel sheet-piling; Comparative merits
Power house design—some good example.
Stresses in conical and spherical bottomed steel tanks.
Irrigation investigations and works of the United States government.
Irrigation works.
Irrigation works and stream measurements.
Hydraulic works.
Artesian wells.
Modern methods for deep water supply.
Water works for small cities and towns.
Water filtration.
Purification of water for domestic use.
Purification of inorganic water, fitting it for domestic use.
Sedimentation schemes.
Water waste in our city water supply and its prevention.
The sanitary arrangement and maintenance of contractors' camps, including designs for bunk houses, dining rooms, commissary offices, etc.
Sanitary sewerage.
Sewage disposal for an inland town.
Steam turbines. (Two requests.)
The steam turbine vs. the reciprocating steam engine, for large electrical units.
Lubrication.
The expert system applied to lubrication.
Boiler designs.
Do chemical analyses or even special boiler tests give the true fuel value of a bituminous coal for every day purposes?
Descriptions of steam shovels, machine tools, factory drives, etc.
Entropy.
Modern ice making machinery.
Steam condensing machinery.

Comparative costs and merits, in large power houses with steam turbines and reciprocating engines.
Gas engines.
Gas producers for power gas.
The transmission of power gas from mines to cities.
The original cost of electric power plants of various capacities operated by steam as compared with similar installations operated by producer or other power gas.
Comparative cost of installation and operation of steam and gas for power plant equipment.
Use of low grade alcohol in internal combustion engines. Also as to advisability of removing the tax on the same.
Producer gas for small power plants.
The present status of the gas engine, especially in connection with blast furnaces and producer plants.
Facts about the gas producer, and the possible use of same for cheap Illinois coals.
Relative advantages and disadvantages of rotary converters; vs. motor operators.
Economics in operation of light and power stations.
Printing telegraph.
Automatic telephone.
Lockout devices on telephone party lines.
The design of electro magnets for alternating currents.
Electric light plants.
Automobile-motors of various kinds. First cost, maintenance, sizes in common use, efficiency, comparative cost of operation, etc.
The single phase motor for railway use; also for crane service.
Storage battery development.
Wireless telegraph system as used by the De Forrest Co., at St. Louis and in Chicago.
Cost of operation and advantages of large electric auto-trucks as used in Chicago.
Thordalson's high voltage transformer.
Masonry construction.
Minimum thickness of arches of small span, built of stone, brick or concrete. Ditto as to large sewers and tunnels.
New dam at Kankakee.
Concrete arch bridge at Kankakee.
Design of reinforced concrete arches.
Portland cement manufacture.
Use of concrete piles.
Reinforced concrete as adapted to railway bridges.
Steel-concrete dams.
Reinforced concrete as a material for railroad trestles in Teredo infected waters.
Concrete building blocks, advantages and disadvantages; also advantages over brick or wood for the cheaper class of small buildings, etc.
Practical steel concrete construction.
Concrete linings for canals in cold climates.
Armored concrete pipe 48-in. to 72-in. dia. for pressures due to 50 to 100-ft. head of water. Method of laying in place in trench, forms and handling, reinforcing rods, hoops, etc. Cost, etc. Means of preventing leakage.
Construction of concrete bridge abutments for railway bridges.
Continuance of the discussion of reinforced concrete.
Comparative strength of concrete made with coarse mixed sand and crushed stone screenings.
Mortar facing for concrete works.
Modern concrete-steel work.
Railway ties of concrete steel.
Long span reinforced concrete railway bridges.
Reinforced concrete.
Design of reinforced concrete buildings.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING--November 2, 1904.

A regular meeting of the Society (No. 530) was held in the rooms of the Society, Monadnock block, November 2d, 1904.

The meeting was called to order at 8:20 p. m., with Mr. W. L. Abbott in the Chair, and about 65 members and guests present.

The Minutes of the meeting held October 5th were read and accepted.

A report from the Board of Direction announced that the following persons had been elected into membership of the Society at their meeting, held November 2d:

A. T. Grohmann, Chicago, Active.
Frederic W. Lucke, Chicago, Associate.
Chas. A. S. Howlett, Chicago, Active.
Edward J. Kelly, Chicago, Active.
Augustus J. Reef, Carterville, Ill., Junior.
Charles W. Wilkes, Chicago, Active.
Frederic H. P. Howard, Beloit, Wis., Junior.
Charles T. Anderson, Chicago, Active.

Also that the following new applications for membership had been received:

Carl William Birch-Nord, Chicago, Junior.
Lewis E. Ashbaugh, Ames, Iowa, Active.
Elmer E. Hanna, Evanston, Ill., Active.
Wm. H. Beattys, Jr., advance from Junior to Active.
Lyle S. Abbott, Chicago, Junior.
Carl P. Schroeder, Chicago, Active.
William R. Wendland, Chicago, Junior.
Gustav F. Jedlicker, Chicago, Active.

A report from the committee appointed to award the Octave Chanute medals to the authors of the most meritorious papers presented during the year 1903 on Civil, Mechanical and Electrical Engineering was as follows:

Under the head of Civil Engineering, to Prof. A. Marston, for his paper on "Sewage Disposal in Iowa."

Under the head of Mechanical Engineering, to Prof. Storm Bull, for his paper on "The Use of Superheated Steam."

Under the head of Electrical Engineering, to Mr. E. Gonzenbach, for his paper on "The Third Rail for High Speed Electric Service."

The Secretary read a letter from Mr. Chanute, dated October 29th, stating that Mr. James Forrest, Honorary Secretary of the British Institution of Civil Engineers, had expressed, in a letter to him, the gratification of the British Institution at the warm welcome and the hospitable way in which their visiting members had been entertained while in Amerca.

The Secretary also read a letter from Messrs. Roberts, Schaefer and Company, Chicago, announcing the death on October 6th of one of their employes, Mr. Bert Fankboner, a Junior member of the Society.

On motion of Mr. Finley, the President was requested to appoint a committee to prepare a suitable memorial on the death of Mr. Fankboner.

Mr. Emil Probst, of Vienna, Austria, then presented his paper on "The Development of Reinforced Concrete in Europe and New Ideas in Construction Work." The paper was illustrated by a number of lantern slide views.

Discussion followed from Messrs. W. L. Abbott, Ernest McCullough, Finley, Seafert, Spelman, Condron and Probst.

A vote of thanks was tendered to Mr. Probst, on behalf of the Society, for his interesting paper.

The meeting adjourned about 10:15 p. m.

EXTRA MEETING—November 11, 1904.

An extra meeting of the Society (No. 531), being the 4th regular meeting of the Electrical Section, was held in the rooms of the Society Friday evening, November 11th.

The meeting was called to order at 8:20 p. m., with Mr. W. B. Hale, Chairman of the Section, in the Chair, and about 100 members and guests present.

The Minutes of the meeting of October 14th were read and approved. The Secretary announced informally that there would be an excursion of the Society to St. Louis and Thebes November 17th to 20th, inclusive. The Chairman announced that the next meeting of the Electrical Section would be held December 16th.

Mr. S. G. McMeen, M. W. S. E., then presented his paper on "Some Interesting Phases of Long Distance Telephony," and discussion followed from Messrs. Lockwood, McBerty, K. B. Miller, Winston, Hale, Watkins, Edson and McMeen.

The meeting adjourned about 10:30 p. m.

EXTRA MEETING—November 23, 1904.

An extra meeting of the Society (No. 532) was held in its rooms, Monadnock block, Wednesday evening, November 23d. The meeting was called to order by Past President Modjeski in the Chair at 8:20 o'clock, with about 75 members and guests present.

Before the reading of the paper by Mr. Strauss, the Secretary read the following statement: "The Secretary desires to say that the paper on Bascule Bridges, to be presented tonight, is in the form as prepared by the author. The paper, however, and the discussion of the same, will be submitted to the Publication Committee before being printed in the Journal of the Society."

Mr. Strauss was then introduced and gave a condensed resumé of his paper. Following this, written discussion was presented from Messrs. Dun, Hughes, Parsons, Cowing, Watson, Cummings and Scherzer; also some commendatory letters were read, which, however, did not discuss the paper. Oral discussion followed from Messrs. Ericson, Finley, Modjeski, Vent, Reichmann, West, Roemheld, Bainbridge, von Babo, Dart, Shnable, Strobel, Bley and Strauss.

During the discussion Mr. Bley offered the following motion, which was carried: "I move that Mr. Strauss be requested to submit a description of each of the bridges mentioned in his paper to the people interested in that bridge, for correction; also that the Publication Committee be instructed to publish, in connection with Mr. Strauss' paper, a copy of the report made to the City Engineer by Mr. von Babo on "Movable Bridges with Special Reference to Bascule Bridges," and a copy of the report of the Board of Consulting Engineers made to the City Engineer in July, 1900."

The meeting adjourned at 10:30 p. m.

REGULAR MEETING—Dechemer 7, 1904.

A regular meeting (No. 533) was held in the rooms of the Society Wednesday evening, December 7th. The meeting was called to order at 8:20 p. m. by Mr. W. L. Abbott, Second Vice President, in the Chair, and about 80 members and guests present.

The Minutes of the meetings of November 3d and 23d were read and accepted.

The Secretary reported, on behalf of the Board of Direction, that the following persons had been elected to membership in the Society, at their meeting, held December 6th:

Edward J. Schneider, Kansas City, Mo., advanced to Active.
Carl Weber, Chicago, Active.

Edward Dvorak, Chicago, Associate.
Durl P. Ruger, Chicago, Associate.
Edward F. Pierce, Chicago, Associate.
Wm. McK. Bayne, Chicago, Associate.
Carl W. Birch-Nord, Chicago, Junior.
Lewis E. Ashbaugh, Ames, Iowa, Active.
Elmer E. Hanna, Chicago, Active.
Wm. H. Beattys, Jr., advanced from Junior to Active.
Carl P. Schroeder, Chicago, Active.

Also that the following new applications for membership had been received:

Austin Kimble, Chicago.
Sutton Van Pelt, Sawyerville, Ala., advanced from Junior to Active.
Frank W. Yale, Coffeyville, Kas.
L. Gustav Hallberg, Chicago.
Julius Floto, Chicago.
Fritz Lubberger, Chicago.
Frank A. Coy, Chicago.
Henry W. B. Clausen, Chicago.
Frank Raymond Coates, Chicago.
John Edwin Crane, Murphysboro, Ill.
Douglas Edward Bonner, Chicago.
Everett Broomall Wilson, Chicago.
Isaac W. Traxel, Aurora, Ill.
Walter J. Warder, Jr., Chicago, advanced from Junior to Active grade.

The Secretary announced that the petitions for nominations for officers for the Society for the coming year had been duly canvassed by the Board of Direction, and, omitting those names which failed to receive the petition of ten members for nomination to office, the result was as follows:

For President—
*W. L. Abbott.
E. C. Carter.
C. W. Hotchkiss.
*G. A. M. Liljencrantz.
For First Vice President—
W. L. Abbott.
*Geo. M. Brill.
G. A. M. Liljencrantz.
For Second Vice President—
W. B. Hale.
C. F. Loweth.
*W. H. Pratt.
For Third Vice President—
I. P. Breckenridge.
Storm Bull
For Treasurer—
Andrews Allen.
Trustee for a term of three years—
P. M. Chamberlain.
Geo. A. Damon.
A. Reichmann.
G. M. Wisner.

The Secretary announced the death of one of the active members of the Society, Mr. L. M. Johnson, and on motion of Mr. Finley, the Chair was requested to appoint a committee to prepare a suitable memorial.

Mr. Liljencrantz moved that a vote of thanks be extended to Mr. F. H. Britton, Vice Prest. & Gen. Mang. of the St. Louis Southwestern Railway; Mr. C. S. Clarke, Vice Prest. Missouri Pacific Railway System; Mr. H. L.

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* These names were subsequently withdrawn and do not appear on ballot.

Magee, Gen'l Supt. Wabash Railroad Co., and A. Robertson, General Manager of the Terminal Railroad Association, all of St. Louis; also to Mr. W. J. Jackson, Gen'l Supt. C. & E. I. R. R., and Mr. J. T. Harahan, 2nd Vice Prest. I. C. R. R., for courtesies extended to the Society on the occasion of the recent excursion to St. Louis and Thebes, Ill.

The Secretary read a letter which had been received from President Parkhurst, who is at present in Georgia on account of his health, stating that it was his desire and hope to be present at the annual meeting of the Society, to be held in January.

Mr. A. F. Robinson, Bridge Engineer of the Atchison, Topeka & Santa Fe Ry., was then introduced, who opened the discussion of the subject for the evening, "Ballasted Bridge Floors." The subject was further discussed by Messrs. Cartlidge, Finley, E. H. Lee and E. N. Layfield.

At the conclusion of the discussion, Mr. Liljencrantz offered a vote of thanks to Mr. Robinson, on behalf of the Society, for his interesting talk, which was unanimously carried.

The meeting adjourned at 10:45 p. m.

EXTRA MEETING—December 16, 1904.

An extra meeting of the Society (No. 534), being the fifth regular meeting of the Electrical Section, was held in the rooms of the Society Friday evening, December 16th.

The meeting was called to order at 8:15 p. m., with Mr. W. B. Hale, Chairman of the Section, in the chair, and about 65 members and guests present.

The Minutes of the meeting of November 11th were read and approved. The Chair announced that by the rules of the Electrical Section, nominations for officers of the Section were in order, the same to be posted on the bulletin board in the Society rooms. He also stated that the election of officers and members of the Executive Committee would be held at the next regular meeting Friday, January 13, 1905.

The Secretary stated that the following had thus far been put in nomination for the Executive Committee:

W. B. Hale, Chairman.

S. G. McMeen, Vice Chairman.

Members of the Executive Committee—W. G. Carlton, Geo. A. Damon, P. B. Woodworth.

Prof. Henry Crew, of Northwestern University, Evanston, Ill., was then introduced, who addressed the meeting on "The Modern Theory of the Arc and Spark." This was illustrated by a few lantern slides.

Discussion was offered by Messrs. Wiler, Hale, W. E. Williams, Eastman and Crew.

The Chairman announced that the next meeting of the Section will be held Friday, January 13th, when Mr. Chas. A. S. Howlett will address the Section on "The Commercial Aspect of Engineering."

Mr. Cravath moved a vote of thanks to Prof. Crew for his address, which was carried.

The meeting adjourned at 9:40 p. m.

EXTRA MEETING—December 21, 1904.

An extra meeting (No. 535) of the Society was held in its rooms in the Monadnock Block Wednesday evening, Dec. 21.

The meeting was called to order at 8:15 p. m. with Second Vice-President Abbott in the chair and about 35 members and guests present.

The papers for the evening was on "The Construction of parts of the Intercepting Sewers of Chicago from 39th street to 63rd street." Mr. W. A. Shaw, M. W. S. E., first presented his paper dealing with the work under his charge alongside of the I. C. R. R., from 39th Street to 51st Street. The second part—from 51st Street to 63rd Street—was constructed under the care of the late Mr. Guy Miltimore, M. W. S. E. His paper as prepared by him just prior to his death, was virtually complete and was read by the Secretary. After the reading of the papers, a number of lantern slide views of the work in progress, etc., were shown which were explained by Mr. Shaw. Discussion followed from Messrs. Abbott, Springer, Shnable, Reynolds, Warder, Stern, Ashley, Wilcox and Shaw.

Meeting adjourned 10 p. m.

J. H. WARDER, *Secretary.*

BOOK NOTES.

Experiments with Alternate Currents of High Potential and High Frequency. Nikola Tesla. 5x6½", 162 pages. 38 figures.. McGraw Publishing Co., New York. 1904. $1.00.

This book is a new edition of a volume published some time since, being a reprint of a lecture delivered before the Institution of Electrical Engineers, London, thirteen years ago. The London lecture was subsequent to an address on the same general subject delivered before the American Institute of Electrical Engineers on May 20th, 1891. The matter contained in the American Institute and London lectures bears upon a field of electrical manifestations explored by Mr. Tesla with a great degree of thoroughness, and with a very much wider range of experimental investigation than any other student to this day. For two reasons the investigations and demonstrations have been found of extreme interest: The potentials are very high, and the frequencies, in comparison with those we are accustomed to consider in connection with commercial alternating current problems, are enormous. In very many ways currents of the high potential and high frequency produced by Mr. Tesla behave in apparently opposite ways to those frequencies and potentials produced by other means. The apparatus which forms the basis for the demonstrations described in this lecture is that involving the insertion of a spark gap in series with condensers and the primary of an oil-immersed step-up transformer. The current furnished to the spark-gap is taken from the secondary of a supplying transformer, and by virtue of the spark at the gap, oscillations in its series primary, produce in the secondary, alternating currents whose frequency is the same as that of the oscillations, and whose potential is that determined by the proportions of the transformer.

The results are startling. Vacuum tubes, containing refractory substances, are caused to light up when connected to the coil by a single wire. Others glow when held in the hand without wire connection of any sort. With properly mounted terminals, phantom streams of light break from the edges of disks and the surfaces of balls. The investigator may cause currents at enormous potentials to pass through his body without injury, and perhaps with no noticeable physiological result. It is in this book that Mr. Tesla pays so great a tribute to the genius and contributory work of Sir William Crookes.

Included in the volume is a communication to the Electrical World and Engineer, of March 5th, 1904, under the title "The Transmission of Electrical Energy without Wires." The proposed transmission is not merely of communication, but of the distribution of power as well; and the tenor of the contribution may be gleaned by a reading of the following astonishing sentence:

"When the great truth accidentally revealed and experimentally confirmed is fully recognized, that this planet, with all its appalling immensity, is to electric currents virtually no more than a small metal ball and that by this fact many possibilities, each baffling imagination and of incalculable consequence, are rendered absolutely sure of accomplishment; when the first plant is inaugurated and it is shown that a telegraphic message, almost as secret and non-interferable as a thought, can be transmitted to any terrestrial distance, the sound of the human voice, with all its intonations and inflections, faithfully and instantly reproduced at any other point of the globe, the energy of a waterfall made available for supplying light, heat or motive power, anywhere on sea, or land, or high in the air—humanity will be like an ant heap stirred up with a stick; see the excitement coming!" K. B. M.

Electricity in the Service of Man. R. Mullineux Wilmsley. 6"x9". 1,200 pages; 1,208 figures, and 6 large plates. Cassel & Co., Ltd., London, Paris, New York, and Melbourne. 1904.

This book is a massive volume something of the size of Ganot's Physics, Deschane's Natural Philosophy, or Sylvanus Thompson's Dynamo Electric Machinery. As the title indicates, the treatise attempts to be popular and practical without mathematics of other than algebraic form where possible. The author is Principal and Head of the Electrical Engineering Department of the Northampton Institute, London, and will be recalled pleasantly by many technical men in this country on account of his journey of inspection of the Technical Schools, etc., through the United States, not many months ago.

The title "Electricity in the Service of Man" is not a new one, as Urbanitzky wrote a book under that title in the German language before 1888. In that year his book was translated into English. Two years later a second edition was produced by the original editor and translated by Dr. Wormell, who was then assisted by Dr. Walmsley. In subsequent editions Dr. Walmsley took more and more part in the revision, so that the present edition is most largely a product of his own effort.

As is usual in such works, the author goes back to first principles and early investigators. As one turns the pages he sees in the pictures much that is familiar in form, the laboratory devices for demonstrating electrostatics being quite unchanged, though some of them have an age of three score years and ten. In the chapter dealing with later things, such as alternating current development and transmission, the theory of electric waves, and its consequent practical application to wireless telegraphy, there is much that is of value in other than historical ways.

A little more than half of the book is taken up by a popular and somewhat technical treatment of most of the electrical services of today, the remaining portion being entitled "The Technology of Electricity;" and in two divisions, covering generation, transmission and the use of electrical power, and the practical applications of small electric currents. Into the second division all problems of telegraphy and telephony, and minor forms of signaling would seem to fall, yet a treatment of these subjects in this second part cannot be discovered. The book ends with some abruptness at page 1192, but by a careful reading of the prefaces and introductions, one gathers the idea that there is more of the book to follow. Indeed, it is implied that a supplemental volume, dealing as fully though not necessarily at so great a length, will treat the omitted sections, and be issued in the near future.

It has become fashionable to refer to technical books as "compilations" unless they bear such distinct marks of originality as to permit the reviewer to forego that form of insult, and comfort himself by an attack on the timeliness or usefulness of the contributed originality. It is highly probable that the author of this useful volume might not care to call it much more than a compilation. It is conceivable, however, that he might with due modesty respond, that while he undertook a compilation, he attempted to do it faithfully and with thoroughness. That he has fulfilled the spirit of this attempt no one handling the volume can doubt. Nor will any one regret that he has had the courage to begin and finish a work involving so much hardship. The volume deserves a substantial welcome, as there is so much in it containing virtue as an assistance to the memory, and in our day of so great a quality of details requiring memory or easily accessible classified fact, any and all helps are gracious things. S. G. M.

Rock Excavations—Methods and Costs. By Halbert Powers Gillette, New York. M. C. Clark, 1904. Cloth, 5½x7½ in. Pp. 376 XVI. 56 illustrations in text; index and many tables. Price $3.00.

This book is a valuable addition to our rather meagre literature on the subject of rock excavations. The book is particularly valuable from the many tables it contains of the cost of doing work in a great variety of situations and in varying qualities of rock. The importance of having a good blacksmith, and the supplying him with good steel for drills, is presented in the first chapter. This is frequently one of the weakest parts of many quarry organizations. The steel is not of as good a grade as should be, and the smith sends the drills to the work not properly shaped and hardened.

The sticking of drills in seamy ground, mentioned by the author in Chapter 5, may be greatly remedied by shaping the end of the drill bits so that the shoulders of the cutting edges extend up the body of the drill a greater distance than usual, and of the same diameter as the cutting edge. This will have the tendency to hold the drill in proper alignment in the hole.

The proper shape of the drills has much to do with their successful operation; this shape and dressing depending on the character of the material to be drilled. In some cases good power drills have been condemned and discarded because of ignorance of this matter. There was a case in Southern Illinois where the power drills were thrown out, as they did not work satisfactorily in shaley, sticky material. Upon changing the shape of the bit and using a sand pump with a sharp cutting edge to clean out the holes, a great improvement was obtained, increasing the rate of sinking the shaft from 1½ ft. to 5 ft. per day.

Drilling contests are noted in this book as well as some of the Trade Journals, but such results are a poor guide to one about to invest in drilling tools, as his conditions, character of rocks, etc., may be altogether different from those used in the drilling contest. To make a proper selection of a drill is after an extended trial, with careful records of progress made, rate of drilling, character of rock, cost of maintenance, supplies, etc.

The Electric Drill has friends, and some remarkable work is noted upon Page 93, which seems to be almost too much, as compared with the standard air or steam drills, which the writer believes to be the superior machine of today in execution and general working qualities.

The loading and hauling of rock is considered by the author quite fully, as was the case with earth in his previous book on "Earth Excavation," and is worthy of careful study by those called upon to estimate for such work.

The Cost of Diamond drilling is also considered by the author, and in addition to his notes, mention may here be made of further information on this subject in "Mines and Minerals," November, 1903, by J. N. Justice on "Rock Drilling in West Africa." Also in "Engineering News" in April, 1903, Mr. C. J. Gray, Commissioner of Mines, Natal, Africa, gives information on the cost of such work.

The Pneumatic hand drill for plug drilling in quarry operations, has some great advantages; the rapidity of drilling short holes being remarkable, and much in advance of the "Baby" drill which has been a favorite for such work.

The subject of railroad tunnel work is also well handled with data of cost of work done, that is interesting.

Take it all in all, the book well merits the careful attention of all interested in the broad, general topic of Rock Excavation.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and in completing valuable volumes for our files.

Since the issue of the JOURNAL for October, 1904, we have the pleasure to report the following additions to the library and gifts from donors named:

BOOKS PURCHASED.

Bowie, Aug. J., Jr.., "Hydraulic Mining in California." 1900.
Burnley, James, "History of Wool and Woolcombing." 1889.
Cooke, M. C., "Introduction to the Study of Fungi." 1895.
Dolezalek, Freidrich, "Theory of the Lead Accumulator." 1904.
Farrington, Oliver C., "Gems and Gem Minerals." 1903.
Fricker, Dr. Karl, "The Antarctic Regions." 1900.
Getman, F. H. "Laboratory Exercises in Physical Chemistry." 1904.
Goss, W. F. M., "Locomotive Sparks." 1902.
Jackson, Holmes C., "Laboratory Work in Physiological Chemistry." 1903.
Jamison, Alpha Pierce, "Elements of Mechanical Drawing." 1904.
Leach, Albert E., "Food Inspection and Analysis." 1904.
Matthews, J. Merritt, "The Textile Fibers." 1904.
Patton, W. M., "A Practical Treatise on Foundations." 1903.
Richards and Woodman, "Air, Water and Food." 1904.
Richards, J. W., "Aluminium." 1896.
Roget, Peter Mark, "Animal and Vegetable Physiology." 1867.
Sabin, Alvah Horton, "Technology of Paint and Varnish." 1904.
Sondericker, Jerome, "Graphic Statics." 1903.
Steinmetz, C. P., "Elements of Electrical Engineering." 1902.
Watson & Burbury, "Mathematical Theory of Electricity and Magnetism."
Wilson, Victor T., "Free-Hand Lettering." 1904.

MISCELLANEOUS GIFTS.

Mead, D. W., M. W. S. E., Chicago, "Notes on Hydrology," 1904. Cloth.

John Bale, Sons & Danielsson, Ltd. London, "Automatic Surveying Instruments," by Thos. Ferguson. Cloth.
Hill, C. S. (Engineering News, New York) "Reinforced Concrete," by Buel & Hill, 1904. Cloth.
Mills, Gen. Anson, U. S. Commissioner, Proceedings, International Water Boundary between United States and Mexico, 1903. Two volumes, half leather bound.
Tratman. E. E. R., M. W. S. E., Chicago, seven pamphlets,
  Tests of Reinforced Concrete Beams, by Talbot.
  "Different Applications of Steam Turbines," by Rateau.
  Rules and Regulations Governing System of Awards, Louisiana Purchase Exposition, 1904.
  Official Classification of Exhibit Departments, Louisiana Purchase Exposition.
  Douzieme Assemblee Generale, Union Internationale Permanente de Tramways, 1902.
  Congres International de Tramways et de Chemins de fer d'interet local. 1902.
  Proceedings of the American Water Works Association for 1904.
Buckley, E. R., State Geologist, Missouri,
  The Geology of Miller County, by Ball and Smith, 1903. Vol. 1 Pam.
  The Quarrying Industry of Missouri, 1904. Vol 2. Cloth.
McGraw Publishing Co., New York, Experiments with Alternate Currents of High Potential and High Frequency. By Nikola Tesla. Cloth.
Library of Congress, Washington, D. C. A. L. A. Catalogue for 1904. Cloth.
Interborough Rapid Transit Co., Edward P. Bryan, "The New York Subway, its Construction and Equipment, 1904." Cloth.
Department of Public Works, Chicago, 28th Annual Report for 1903. Cloth.
Colorado School of Mines, Golden, Colo. Catalogue 1904-5. Pamphlet.
Illinois Steel Co., Cement Department, Chicago, 2 books. Cloth.
  Report of Committee on Standard Specifications for Cement. 1904.
  Facing and Finishing Exposed Concrete Surfaces. 1904.
Producers' Supply Co., Chicago, "Crushed Stone and Its Uses," by W. J. Jackman. 1904. Cloth.

GOVERNMENT PUBLICATIONS.

U. S. Department of Agriculture, Bureau of Forestry, pamphlets,
  The Basket Willow, by W. F. Hubbard.
  Forest Planting in Western Kansas, by R. S. Kellogg.
  Exhibit of Forest Planting in Woodlots at the Louisiana Purchase Exposition.
  Exhibit of a Forest Nursery at the Louisiana Purchase Exposition.
  Chestnut in Southern Maryland, by R. Zon.
  Progress Report on the Strength of Structural Timber, by W. K. Hatt. 1903.
U. S. Department of Agriculture, Experiment Stations, pamphlet,
  Report on Drainage Investigations, 1903. C. G. Elliott.

U. S. Geological Survey, Department of Interior, pamphlets,
Production of Cement in 1903. Kimball.
" " Natural Gas in 1903. Oliphant.
" " Petroleum in 1903. Oliphant.
" " Mineral Waters 1903.
" " Mineral Paints 1903. Pratt.
" " Platinum, 1903.
" " Quicksilver, 1903.
" " Precious Stones, 1903. Kunz.
" " Tin, 1903. Struthers.
" " Gas, Coke, Tar and Ammonia at Gas Works and in Retort Coke Ovens in 1903. Parker.
" " Coal in 1903. Parker.
Statistics of the American Iron Trade, 1903. Swank.

U. S. Department of Commerce and Labor, Bureau of the Census, pamphlets.
Bulletin No. 12, The Executive Civil Service of the U. S.
" " 15, A Discussion of the Vital Statistics of the 12th Census.

U. S. War Department, eight volumes, cloth, annual reports for the year 1903.

U. S. Army, Corps of Engineers, one cloth bound volume, Professional Papers No. 31, "Wave Action in Relation to Engineering Structures," by Gaillard.

U. S. Department of the Navy, Bureau of Steam Engineering. one volume, boards. Report of the U. S. Naval "Liquid Fuel," Board of Tests, on Hohenstein Water Tube Boilers.

EXCHANGES.

League of American Municipalities. Des Moines, Iowa, No. 2, Vol. 2, October, 1904. Pamphlet.

Association of Ontario Land Surveyors, Annual report, 1904, 12th annual meeting. Pamphlet.

Iowa Geological Survey, Des Moines, Iowa, 14th annual report for 1904. Cloth.

American Water Works Association, Proceedings for 1904. Pamphlet.

American Institute of Mining Engineers, Transactions for 1903. Vol 34. Pamphlet.

American Railway Master Mechanics' Association, J. W. Taylor, Sec'y, Chicago. Vol. 37, Proceedings at Saratoga, 1904. Half leather.

New York State Engineer and Surveyor, two volumes, cloth,
Annual report 1903.
Report on the Gaugings of volume of Discharge of Streams in the State of New York, together with report of Co-operative Survey, 1903.

Institution of Engineers and Shipbuilders in Scotland, Transactions 1903-4, Vol. 47. Cloth.

Smithsonian Institution, Washington, D. C. Annual Reports Board of Regents for 1903. Cloth.

American Railway Engineering and Maintenance of Way Association, Pamphlets. Bulletins No. 52 to 57, inclusive, June-November, 1904.

TRADE CATALOGUES.

Smith, Ernest F., M. W. S. E., Chicago, St. Joseph Boat Manufacturing Co., St. Joseph, Mich. Pamphlet.

Crocker-Wheeler Co., Chicago, Bulletin No. 35, Equipment of a Railway Shop. Pamphlet.

Hooven, Owens, Rentschler Co., Hamilton, Ohio, "The Hamilton Holzwarth Steam Turbine." Pamphlet.

Sullivan Machinery Co., Chicago, "The Sullivan Mining Machine for Undercutting Coal in Room and Pillar Mines." Pamphlet.

"Modern Practice in Air Compression." Catalogue No. 53, 1904. Pamphlet.

Northwestern Expanded Metal Co., Chicago, "Fireproof Building Construction for Floors, Roofs, etc." Also "Reinforced Concrete Construction." Pamphlet.

Dodge Manufacturing Co., Mishawaka, Ind., "The Construction of a Modern Cement Plant." Pamphlet.

WESTERN SOCIETY OF ENGINEERS

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LIST OF OFFICERS FOR 1904

President	H. W. Parkhurst
First Vice-President	C. W. Hotchkiss
Second Vice-President	W. L. Abbott
Third Vice-President	Prof. W. D. Pence
Treasurer	Andrews Allen

TRUSTEES

J. W. Alvord	Term expires January, 1905
B. E. Grant	Term expires January, 1906
T. W. Snow	Term expires January, 1907
O. Chanute, W. H. Finley, R. Modjeski	Past Presidents.

The above named officers of the Society and three past presidents, constitute its Board of Direction

Secretary and Librarian
J. H. WARDER

COMMITTEES

On Finance—C. W. Hotchkiss, Andrews Allen, C. F. Loweth.

On Publication—W. L. Abbott, E. E. R. Tratman, John Brunner, G. M. Brill, W. B. Hale.

On Membership—W. H. Finley, W. H. Baldwin, Geo. A. Damon.

On Library—B. E. Grant, J. W. Alvord, A. Reichmann.

On Entertainment—G. A. M. Liljenkrantz, W. J. Karner, J. G. Bergquits, A. R. Eldridge, W. C. Armstrong.

MEETINGS

Regular Meeting—1st Wednesday evening of each month except January July and August.

Extra Meeting—3rd Wednesday evening of each month except July and August.

Board of Direction—The Tuesday preceding the 1st Wednesday of each month.

NOTICE

From the dues of each member, $2.00 is set aside as a subscription to the Journal.

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